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2020

PROCEEDINGS

OF

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PAPERS PRESENTED AT THE ANNUAL MEETING

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PREFACE

The Proceedings contain the written abstracts of the papers and posters presented at the 2020 Western Society of Weed Science and Weed Science Society of America joint annual meeting plus summaries of the research discussion sections for each WSWS Project. The number located in parenthesis at the end of each abstract title corresponds to the paper/poster number in the WSWS/WSSA Meeting Program. Authors and keywords are indexed separately. Index entries are published as received from the authors with minor format editing.

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The Minutes of the Board of Directors meetings and the Business Meeting are available at the WSWS website.

Proceedings Editor: Carl Libbey

GENERAL SESSION

Introductions and Announcements. William S. Curran* and Corey V. Ransom; Penn State University, University Park, PA and Utah State University, Logan, UT (610)

Abstract not available

IWSS Organization and Meeting Update. Nilda Roma-Burgos*; University of Arkansas, Fayetteville, AR (611)

Abstract not available

Keynote: Hawai'i: A World of Weeds in Microcosm. Samuel M. 'Ohukani'ohi'a Gon III*; The Nature Conservancy of Hawaii, Honolulu, HI (612)

Abstract not available

Presidential Address. Larry Steckel*[1], Pat Clay[2]; [1]University of Tennessee, Jackson, TN, [2]Valent U.S.A. LLC, Fresno, CA (613)

Abstract not available

Presentation of Awards. William S. Curran*[1] and Pat Clay*[2]; [1]Penn State University, University Park, PA, [2]Valent U.S.A. LLC, Fresno, CA (614)

Abstract not available

POSTER SESSION

WSWS Project 1. Weeds of Range, Forest, and Natural Areas

WSSA Section 4. Pasture, Range, Forest, Rights of Way, Wildland, and Aquatic Invasive Plants

Addressing Challenges of African Mustard (*Brassica tournefortii*) Management in Utah. Natalie L. Fronk*[1], Corey V. Ransom[1], Benjamin Scow[2], Chad Reid[3]; [1]Utah State University, Logan, UT, [2]Utah State University Extension, Hurricane, UT, [3]Utah State University Extension, Cedar City, UT (121)

African mustard (*Brassica tournefortii)* is a highly competitive invasive annual found in the Southwestern United States with limited distribution in Utah. As infestations in Utah extend into a variety of management areas with different restrictions and priorities, stakeholders require varied and effective management solutions. To investigate these solutions, field trials were established in 2017 and 2018 to evaluate herbicide combinations, timings, and hand-weeding for African mustard control. Treatments were applied to 3 by 9 m plots arranged in a randomized complete block design replicated 4 times. For the 2017 trial, preemergence and postemergence treatments were applied December 13, 2017 and March 6, 2018. The 2018 trial applications were made on October 1, 2018 and January 11, 2019. The trials were similar except that in the 2018 trial a lower rate of indaziflam replaced the high rate from the 2017 trial and the hand-weeding treatment was omitted. May 2018 evaluations of the 2017 trial found that all herbicide treatments provided 100% control of African mustard with the exception of the low rate of 2,4-D, which provided 89% control. The 2019 evaluation of this trial found all indaziflam treatments and imazapic maintained 100% control. Unfortunately, 2,4-D, metsulfuron, and imazapic caused significant injury to indigo bush. Hand-weeded plots provided minimal reduction in African mustard density. For the 2018 trial, evaluation in March 2019 found 100% control for all treatments. Indaziflam at an extremely low rate of 15 g ai/ha provided complete control. A preliminary dose response trial evaluated African mustard root growth in agar plates. From this experiment it appears that African mustard is much more sensitive to indaziflam than other species described in existing literature. These trials suggest that effective management options are available for African mustard management.

Using Unmanned Aerial Systems for Estimating Biomass of Smutgrass (*Sporobolus indicus*) and Management Interventions. Zachary S. Howard*[1], Bishwa B. Sapkota[1], Chenghai Yang[2], Muthukumar V. Bagavathiannan[1], Scott A. Nolte[3]; [1]Texas A&M University, College Station, TX, [2]USDA-ARS, College Station, TX, [3]Texas A&M AgriLife Extension, College Station, TX (122)

Smutgrass (*Sporobolus indicus)* present in pastures can significantly impact forage quantity and quality, and current herbicide management strategies are either costly or detrimental to the desired forages. Remote sensing based site-specific weed management (SSWM) can not only lead to effective utilization of herbicides, but also foster a healthy physical and socioeconomic environment. In this study, multispectral imageries were analyzed using advanced algorithms to produce mature smutgrass distribution maps, that could be further subjected to SSWM. The pasture land was delineated into high and low smutgrass density zones and four mature smutgrass individuals were chosen in each zone for ground truth data (biomass and height). A Homeland Surveillance & Electronics Unmanned Aerial Vehicle was flown at 40 m to capture images in 4 bands (Blue, Green, Red, Near-infrared), imageries were then georeferenced and radiometrically corrected. The imageries coupled with canopy height model derived using structure from motion technique were fed into object-based image analysis (OBIA) algorithm followed by machine learning algorithm. The OBIA algorithm segments the image into homogeneous groups of pixels based on pre-defined criteria and the machine learning algorithm classifies the segmented objects into use-defined classes based on the training data the user provides. Preliminary results show that the fusion of multispectral and 3D information has potential to produce accurate smutgrass distribution maps.

Ventenata (*Ventenata dubia*) Control and Plant Community Response to Herbicide Treatments. Hailey L. Buell*, Corey V. Ransom, Steve Young; Utah State University, Logan, UT (123)

Ventenata is a highly invasive annual grass native to Eurasia and North Africa that has been a problem in the western United States for the past decade and has only recently been discovered in Utah. This project was designed to test the efficacy of various herbicides alone and in combination with indaziflam on ventenata, and to measure plant community response. Two trials were established near Mt. Sterling, Utah, one in 2017 and another in 2018 with some adjustments to treatments in 2018. Herbicides were applied to 6 by 18 m plots arranged in a randomized complete block design replicated four times. Species cover was evaluated using point-line-intercept transects, recording a point every 15 cm. In 2017, only treatments including rimsulfuron or indaziflam controlled ventenata in the first year, reducing cover to less than 1%. In the second year, ventenata cover increased in seven of eleven treatments including three of the five indaziflam treatments. Glyphosate and imazapic alone were less effective than rimsulfuron. Wild onion increased in four of five of the indaziflam treatments excluding indaziflam + rimsulfuron; likewise, overall species richness increased in four of the five excluding glyphosate + indaziflam at the highest rate. Richness was only decreased with imazapic alone. Three of the indaziflam combinations increased total broadleaf cover, but this included increases of bindweed in some plots. The 2018 trial largely mirrored the 2017 trial, except that imazapic alone applied early fall controlled ventenata in the first year and indaziflam treatments significantly reduced tarweed cover. In both trials, aminopyralid nearly doubled ventenata cover due to reductions in broadleaf plants. Annual grass suppression for more than one year allows resurgence of desirable and weedy perennial plants. This project provides understanding on how herbicide treatments and combinations affect plant community dynamics in systems invaded by ventenata.

Tolerance of Native Perennial Grasses to Esplanade on Conservation Reserve Program Land. Jared A. Beuschlein*[1], Rachel J. Zuger[1], Harold Quicke[2], Ian Burke[1]; [1]Washington State University, Pullman, WA, [2]Bayer, Windsor, CO (124)

Invasive annual grasses, particularly ventenata, are problematic in Conservation Reserve Program land throughout Eastern Washington and Northern Idaho. Indaziflam is a new herbicide which can control ventenata. However, there is limited knowledge on how desirable perennial grasses tolerate indaziflam. Desirable grasses assessed were bluebunch, slender, and intermediate wheatgrass; Idaho and sheep's fescue; and prairie junegrass. The objective was to compare indaziflam with and without tank-mixture partners assess how desirable perennial grasses tolerate indaziflam. Two randomized complete block design studies were conducted in 2018 and 2019. Treatments included indaziflam (44 g ai ha^{-1}, 73 g ai ha^{-1}, 102 g ai ha^{-1}), rimsulfuron (52.5 g ai ha^{-1}), propoxycarbazone (59 g ai ha^{-1}), imazapic (123 g ai ha^{-1}) and imazamox (44 g ai ha^{-1}). Biomass was collected 4 and 15 mo after treatment (MAT) by harvesting two 1/10 m^2 quadrats. Coverage was assessed using a 4 m transect with presence and absence of species. Sheep's fescue biomass (56 g m^2) was 48% higher when indaziflam and imazamox was applied for annual grass control compared to the nontreated (29 g m^2). The combination of all perennial grass biomass was 62% higher (at 2610 kg ha^{-1}) when treated with indaziflam plus propoxycarbazone, indaziflam plus imazapic, or indaziflam plus imazamox compared to the nontreated (167 kg ha^{-1}). Perennial grass coverage was

47% higher for the indaziflam plus imazamox treatment (94%), compared to the nontreated (50%). The native desirable perennial grass species we assessed have a tolerance to indaziflam treatments a year after treatment.

Evaluating Historical Treatments to Clarify Optimal Herbicide Treatment Sequences for Invasive Old World Climbing Fern (*Lygodium microphyllum*) on Tree Islands of the Florida Everglades. Jonathan Glueckert*[1], Stephen F. Enloe[2]; [1]University of Florida, Boynton Beach, FL, [2]University of Florida, Gainesville, FL (125)

Old world climbing fern (OWCF) is an invasive fern that threatens the integrity of freshwater wetlands in peninsular Florida. One of the greatest areas of invasion has been within the northernmost remnant of the Everglades, the Arthur R Marshall Loxahatchee National Wildlife refuge. Loxahatchee NWR is a 59,647-ha wetland that is composed of mixed emergent marsh communities and unique tree islands that harbor tremendous biological diversity. OWCF Management efforts involve either aerial or ground crew herbicide applications on the tree islands and re-treatment is generally necessary. However, limited resources, geographic isolation, and seasonal difficulty in access may limit the ability of crews to revisit islands for several years. Given this issue, defined re-treatment interval timings would assist managers greatly in determining the need to revisit previously treated areas. To address this, historical data from 2014-2018 was queried to find islands that were treated by backpack application once with glyphosate and never subject to a re-treatment. Selected islands were then intensively sampled with eight 1x3m plots to quantify OWCF cover initiating from both rhizomes and new sporelings, native plant cover, bare ground, and delineate OWCF recovery from the island exterior (perimeter) and island interior. Preliminary analysis of islands treated over the previous four years did not suggest a trend in OWCF cover from rhizome regrowth over time. However, sporeling cover was higher on more recently treated islands. Landscape position within islands strongly affected OWCF regrowth, with interior portions having lower cover than exterior areas. Native plant cover also varied by landscape position with some evidence of lower cover on islands with more recent treatment timings. In general, these findings indicate that while predicting re-treatment intervals may not be clear cut, a new strategy of increased monitoring and re-treatment of tree island perimeters may be useful in protecting tree islands from OWCF dominance. Future studies should examine the trade-offs in whole island monitoring and treatment versus perimeter monitoring and treatment.

Phragmites australis In Colorado: Haplotype Distribution and Molecular Tools for Management Decisions. Neeta Soni*[1], Eric L. Patterson[2], Luke Tembrock[1], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Michigan State University, East Lansing, MI (126)

Phragmites australis (common reed) is a cosmopolitan species distributed across continents worldwide. In the United States, *Phragmites* haplotypes have been identified in 3 main groups: (1) introduced (Eurasian origin); (2) native (North American origin); and (3) Gulf Coast (cryptogenic origin). Native *Phragmites* haplotypes represents an important component of the natural ecosystem, whereas introduced *Phragmites* haplotypes reduces biodiversity by rapidly displacing native *Phragmites* haplotypes and other species. While morphological characters are useful for visual classification of native and introduced haplotypes, they are not completely reliable when *Phragmites* is exposed to drastic environmental conditions due to its plasticity and adaptation abilities; thus, a genotyping method is preferred. The Colorado Department of Agriculture is considering whether to declare introduced *Phragmites* as a noxious weed as a measure to reduce the ecological repercussions that this haplotype can cause. However, the occurrence of introduced *Phragmites* in the state remains unknown. Here we genetically tested 189 samples collected across the state of Colorado, developed a cost-effective genotyping tool KASP (Kompetitive Allele Specific PCR) to discriminate among native and introduced haplotypes, and conducted a phylogenetic analysis to identify possible new haplotypes. We Sanger sequenced two non-encoding chloroplast DNA regions (trnT-trnL and rcbL-psaI) and compared them against reported sequence databases. Samples that sequencing did not produce results were subject to Cleaved Amplified Polymorphic Sequence (CAPS) markers. A KASP assay was designed for same loci used for sequencing and tested on 185 samples. We have identified 119 and 70 samples as native and introduced haplotypes, respectively. The KASP assay accuracy compared to the results obtained by sequencing and CAPS classification was 92%. Phylogenic analysis suggested that the existing haplotypes do not diverge from reported haplotypes. Results from this study provides land managers with accurate information and better tools for conservation and appropriate management of native *Phragmites.*

Woody Debris Piles Facilitate Increased Douglas-fir Survival at a Scotch Broom (*Cytisus scoparius*) Infested Site. James Dollins*, Timothy B. Harrington; USDA Forest Service - PNW Research Station, Olympia, WA (127)

Piling of woody debris soon after forest harvesting is typically practiced In the Pacific Northwest to prepare sites for planting with coast Douglas-fir seedlings. The method has evolved as a site preparation alternative to broadcast burning because of concerns about smoke management and impacts to soil productivity. At two long-term forest productivity studies near Matlock, WA and Molalla, OR, debris-piling was applied to eight 0.3-ha plots prior to planting Douglas-fir in spring 2004. Each plot contained a grid of 100 Douglas-fir seedlings that were tagged to monitor their subsequent development. In 2004, we mapped the locations of each Douglas-fir seedling and debris pile per plot. By 2007, soil disturbances associated with forest harvesting and debris piling at Matlock had stimulated the development of a dense stand of Scotch broom from soil-stored seed; Scotch broom was largely absent at Molalla. Potential proximity effects of debris piles on Douglas-fir survival were identified via two approaches. In the first approach, 15th-year Douglas-fir survival data from each site were subjected to a paired t-test to compare performance of trees growing within 1 m of the edge of a debris pile versus those growing greater than 1 m from a debris pile. At Matlock, survival of trees growing close to piles (86%) was 17 percentage points greater than that of trees growing more distant from piles (69%) (P < 0.01); at Molalla, the difference (3 percentage points) was not statistically significant (P = 0.35). In the second approach, debris pile locations were plotted on 15th-year aerial photographs from Matlock. Three plots were selected to illustrate the observed range in proximity effects of the piles on surviving Douglas-fir trees based on the survival averages from the paired t-test. In two of the selected plots, surviving trees were clustered around pile locations, and Scotch broom cover occupied much of the remaining growing space. Overall survival was high in a third plot and there were no clear signs of clustering of surviving trees around pile locations. We hypothesize that debris piles facilitated increased survival of Douglas-fir at Matlock by providing a refuge from Scotch broom competition. In contrast to Matlock, high levels of tree mortality from a severe competitor did not occur at Molalla; hence, debris piles did not have a detectable influence on Douglas-fir survival at Molalla.

Johnsongrass Management on Roadsides: Control, Suppression, or Selectivity? Joe Omielan*; University of Kentucky, Lexington, KY (128)

Johnsongrass (Sorghum halepense) is a perennial warm-season grass, listed as a noxious weed in Kentucky, that is a common problem on right-of-ways. There are a number of herbicides labeled and available to control johnsongrass on right-of-ways. However, some of these are nonselective or are selective for johnsongrass but can still damage desirable cool-season turf, such as tall fescue. One of the safer johnsongrass control herbicides to use on tall fescue is Fusion but a label change in 2012 made it unavailable for use on right-of-way sites. This trial evaluated a range of johnsongrass control/suppression options along with the damage and recovery of tall fescue after application. Which options resulted in the best control with least damage? The johnsongrass site had late season regrowth (120 cm canopy) and was treated August 30, 2017 in Rowan County KY. The tall fescue trial was established August 27, 2017 at Spindletop Research Farm in Fayette County KY when the plants were 25 cm high. The trial had 20 treatments with three replications arranged in a randomized complete block design with 2.1 m by 6.1 m johnsongrass plots and 1 m by 3 m fescue plots with 0.5 m unsprayed buffers between each of the plots. Application was at 280 L/ha. Johnsongrass control was assessed 23 (9/22/2017), 53 (10/22/2017), and 302 (6/28/2018) days after treatment (DAT). Tall fescue color was assessed every two weeks by comparison to the running check strips. The color rating ranges from 0 (dead) to 9 (full green). The color of the check strips was set at 8. Plots were assessed 14 (9/9/2017), 29 (9/24/2017), 45 (10/10/2017), 57 (10/22/2017), and 75 (11/9/2017) days after treatment (DAT). In the spring tall fescue stand density was assessed visually from 0 (none) to 10 (full stand) 262 (5/15/2018) and 276 (5/29/2018) DAT. Data were analyzed using ARM software and treatment means were compared using Fisher's LSD at $p = 0.05$. All the treatments used the required adjuvants. The 2011 Fusion (fluazifop + fenoxaprop) label rates for selective control of johnsongrass were 7 to 9 fl oz/A (Treatments 1 and 2). The rates on the label for Envoy (clethodim) are 16 and 32 fl oz/A (Treatments 3 and 4). Previous trials had used 13, 15, and 17 fl oz/A to find the best selective rate with less fescue damage. The labeled Fusilade II (fluazifop) rates are 16 to 24 fl oz/A (Treatments 5 and 6). The Acclaim Extra (fenoxaprop) label lists 20 fl oz/A per acre to control seedling johnsongrass 12 – 24 inches tall (Treatment 7); 39 fl oz/A to control rhizome johnsongrass 24 to 60 inches tall (Trt. 8); and a combination of Acclaim Extra plus Fusilade (0.5 plus 3.5 fl oz/A), for improved turfgrass tolerance and to control rhizome johnsongrass 10 to 25 inches tall (Treatment 9). The Outrider (sulfosulfuron) label rates for selective johnsongrass control in tall fescue turf are 0.75 to 1 oz/A (Treatments 10 and 11). Treatment 12 is MSMA (monosodium acid methanearsonate) applied alone (32 fl oz/A) and Treatment 13 is MSMA applied in combination with Outrider at 0.75 oz/A. Clearcast (imazamox) (Treatment 14) (32 fl oz/A) has an aquatic label and may be used close to waterways. The high rate of Plateau (imazapic) (8 fl oz/A) used in Treatment 15 will severely damage tall fescue. Poast Plus (sethoxydim) is a herbicide option we have not tested recently and has control of rhizome johnsongrass up to 25 inches tall on the label for this region of the U.S. (Treatments 16 and 17) (2.25 and 3.75 pt/A). Roundup (glyphosate) (22 fl oz/A) (Treatment 18) and Journey (glyphosate + imazapic) (21.3 fl oz/A) (Treatment 19) are non-selective. Treatment 20 was the unsprayed control. At 53 DAT the top group of treatments had 83 to 93% johnsongrass control with many of the same treatments as at 23 DAT. At the second rating they were the high rate of Fusion (Treatment 2), both rates of Envoy (Treatments 3 and 4), both rates of Fusilade II (Treatments 5 and 6), the high rate of Acclaim Extra (Treatment 8), the combination of Acclaim + Fusilade (Treatment 9), Roundup ProMax (Treatment 18), and Journey (Treatment 19). Next spring at 302 DAT the top group of treatments had 69 to 93% control and many of these were not in the top in the 2017 ratings. At this spring rating they were both rates of Envoy (Treatments 3 and 4), the high rate of Fusilade II (Treatment 6), both rates of Outrider (Treatments 10 and 11), both MSMA by itself and in combination with Outrider (Treatments 12 and 13), Clearcast (Treatment 14), Plateau (Treatment 15), Roundup ProMax (Treatment 18), and Journey (Treatment 19). The treatments showing aboveground control more quickly may not necessarily be the ones with the best long term control. Outrider performed well in our trials but is slower to show foliar control. Some treatments showed good safety on tall fescue with color ratings that were consistently not different from the nontreated check over all the ratings while others showed recovery by the end of the season. Treatments with color ratings consistently not different from control included both rates of Fusion (Treatments 1 and 2), both rates of Acclaim Extra (Treatments 7 and 8), MSMA by itself (Treatment 12) and in combination with Outrider (Treatment 13). Treatments that recovered by 75 DAT included the low rate of Envoy (Treatment 3), both rates of Fusilade (Treatments 5 and 6), the combination of Acclaim + Fusilade (Treatment 9), both rates of Outrider (Treatments 10 and 11), both rates of Poast (Treatments 16 and 17), and Roundup (Treatment 18). The high rate of Envoy (Treatment 4), Clearcast (Treatment 14), Plateau (Treatment 15), and Journey (Treatment 19) did not recover before the end of the season. In the spring the tall fescue stand density improved for many treatments between the two rating dates in 2018. By late May (276 DAT) the top group of treatments had density ratings from 6.8 to 9.0 while the sparsest treatments ranged from 1.2 to 5. The latter group included the high rate of Envoy (Treatment 4), Clearcast (Treatment 14), Plateau (Treatment 15), both rates of Poast (Treatments 16 and 17), Roundup (Treatment 18), and Journey (Treatment 19). These would not be recommended if one wants to preserve existing fescue in the application area.

Response of Seeded Species to Three Common Herbicides Used for Downy Brome (*Bromus tectorum*) Control. Melissa L. Landeen[1], Kevin Gunnell[2], Steve Young*[3]; [1]Utah Division of Wildlife Resources, Ephraim, UT, [2]Utah Division of Wildlife Resources, Fountain Green, UT, [3]Utah State University, Logan, UT (129)

Abstract not available

Pollinator Habitat Diversity and Quantity Increases with Long-Term Cheatgrass (*Bromus tectorum*) Control. James Sebastian*[1], Steve Sauer[1], Shannon Clark[2], Derek J. Sebastian[3]; [1]Boulder County Open Space, Longmont, CO, [2]Colorado State University, Fort Collins, CO, [3]Bayer, Greeley, CO (130)

Abstract not available

Integrated Management of Some Forest Invasive Weeds in B.C. Forestry, Victoria, Canada. Raj Nil Prasad*; Emeritus scientist / prof, Victoria, BC, Canada (131)

Weeds in forestry cause losses in yield of forest products - wood fibre, timber, hydrology, wildlife, and aesthetic values. Several exotic weeds- scotch broom, gorse, daphne surge, English ivy, Himalayan berry, knot weeds, etc were examined. The four weeds scotch broom, daphne surge, English ivy were investigated and their control measures designed by manual cutting, herbicides, mulching and bio-herbicides. Herbicides were found to be most effective followed by other methods. Integrated management is discussed

Genetic Study and Chemical Control of Vaseygrass. Renata Thaysa da Silva Santos*[1], Esteban Fernando Rios[2], Pedro Luis da Costa Aguiar Alves[1]; [1]São Paulo State University, Jaboticabal, Brazil, [2]University of Florida, Gainesville, FL (132)

Abstract not available

Dose-response Curves and Herbicides Efficacy of Pos-emergence Applications in *Paspalum virgatum*. Renata Thaysa da Silva Santos*, Aline Brufato, Pedro Luis da Costa Aguiar Alves; São Paulo State University, Jaboticabal, Brazil (133)

Abstract not available

Management Considerations for Milkweed (*Asclepias viridis*) Habitat in the Southeast. David Russell*[1], John D. Byrd, Jr.[2], Nolan H. Thorne[3], Maria Leticia M. Zaccaro[4], Hayden Quick[2]; [1]Auburn University, Madison, AL, [2]Mississippi State University, Mississippi State, MS, [3]Mississippi State University, Mississippi State University, MS, [4]University of Arkansas, Fayetteville, AR (134)

Since the passing of the 2014 "Presidential Memorandum-Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators", considerable effort from public and private agencies have attempted to understand habitat losses and improve the health of pollinator species in the U.S. Management strategies have therefore, received special attention, specifically regarding integrated vegetation management on agricultural and noncroplands. Two of the most common forms of vegetation management, mechanical and chemical methods, were recently evaluated in north Mississippi to determine its effect on green antelopehorn milkweed, a key species for the monarch butterfly. Milkweed stem counts and qualitative control measurements were taken throughout the study duration to one year after treatments to determine, 1. Effect of timing and frequency of mowing between May to August and, 2. Effect of herbicides commonly used in rights-of-way and forage systems. Results suggest mowing green antelopehorn in monthly or sequential monthly intervals resulted in no negative impact to the number of live stems counted when compared to the nontreated check. At one location, green antelopehorn live stems increased in plots mowed only in June or sequentially mowed in June and again in July. Due to the nature of this perennial species, it appears the majority of the population's growth is completed in August prior to summers end in Mississippi. Based on percent reduction in stem counts from initial treatment to spring the year following application, plots treated with the following herbicides were no different than the untreated at location or year: hexazinone applied at 0.38 and 0.75 lb ai/A, foramsulfuron+iodosulfuron-methyl+thiencarbazone-methyl at 1.1 and 2.2 oz ai/A, aminocyclopyrachlor+chlorsulfuron at 1.4 and 2.8 oz ai/A, metsulfuron-methyl at 0.15 and 0.3 oz ai/A, and sulfosulfuron at 0.03 and 0.06 lb ai/A. In order to achieve effective weed control while maintaining milkweed populations, the following herbicides are suggested for use: aminopyralid at 0.05 and 0.1 lb ae/A, nicosulfuron+metsulfuron at 0.53 and 1.1 oz ai/A, picloram+2,4-D choline at 0.62 lb ae/A, sulfometuron at 0.38 and 0.75 lb ae/A, triclopyr choline at 1 lb ae/A, 2,4-D+dicamba at 0.65 and 1.3 lb ae/A, aminocyclopyrachlor at 0.03,0.06, 0.13, and 0.19 lb ae/A, aminopyralid+2,4-D at 0.46 and 0.93 lb ae/A, chlorosulfuron+metsulfuron at 0.38 and 0.76 oz ai/A, and fluroxypyr at 0.24 lb ae/A. These data indicate that common mowing practices between May and July, as well as many herbicides used for integrated vegetation management do not cause long term declines in milkweed populations.

Long-term Effects of Restoration Treatments in a Wyoming Big Sagebrush Community Invaded by Annual Exotic Grasses. Becky K. Kerns*[1], Dana Ikeda[1], Michelle A. Day[2]; [1]US Forest Service - PNW Research Station, Corvallis, OR, [2]US Forest Service - Rocky Mountain Research Station, Corvallis, OR (135)

Assessing the long-term success of sagebrush restoration treatments is critical for informing future management and treatment strategies since short-term patterns do not generally predict long-term trends. Using a designed experiment from a Wyoming big sagebrush community that was established in 2008, we examined the long-term vegetation response to juniper removal and native seed mix(cultivar or locally sourced) in disturbed and undisturbed areas (slash pile, skid trails, no disturbance). We also examined the landscape scale plant response to juniper removal using repeatedly measured randomly located transects. We found that short-term trends did not predict long-term outcomes. There was some evidence of exotic species suppression owing to seeding with locally sourced “weedy” natives in disturbed areas. At the landscape scale, juniper removal increased total plant cover and perennial bunchgrass cover, but exotic grass cover increased threefold in some areas. Taken together, these results indicate that while juniper removal may increase plant cover, exotic grass invasion complicates restoration outcomes. Even longer-term data is needed to determine restoration outcomes and to test the temporal persistence of exotic grass invasion. Results from our study underscore the idea that restoration success need to be continuously assessed and managed over the long term.

Integrating Common Control Methods for Wild Parsnip (*Pastinaca sativa*) Near Roads with Imazapic + Metsulfuron for Grass Height Suppression. Leo Roth*, Mark J. Renz; University of Wisconsin-Madison, Madison, WI (136)

Roadside rights-of-way (ROW) provide important ecosystem functions, but they also are dispersal corridors for invasive plants. While ROW land managers actively control invasive plant infestations, budget constraints and limited information on effective control techniques often prevent management. To address these limitations, we conducted experiments at two locations in Wisconsin to demonstrate control of wild parsnip (*Pastinaca sativa* (*L*)). Wild parsnip is one of the most common invasive plants in Wisconsin ROW with over 12,000 populations reported throughout Wisconsin. We tested the effectiveness of nine herbicide-based and five mechanical management methods for controlling and preventing seed production of wild parsnip. Because ROW vegetation is typically mowed two to five times per year in Wisconsin, we also compared the effectiveness of imazapic + metsulfuron alone and in combination with aforementioned methods. Imazapic + metsulfuron has been shown to reduce grass height, allowing for a reduction in mowing frequency, potentially saving money while providing invasive plant control. Herbicides broadcasted in May 2019 included aminopyralid (87 g ai ha^{-1}) + metsulfuron (13 g ai ha^{-1}), aminopyralid (142 g ai ha^{-1}) + florpyrauxifen (12 g ai ha^{-1}), aminopyralid (199 g ai ha^{-1}), metsulfuron (21 g ai ha^{-1}), aminocyclopyrachlor (140 g ai ha^{-1}), 2,4-D (529 g ai ha^{-1}) + dicamba (326 g ai ha^{-1}), and indaziflam (40 g ai ha^{-1}). Two treatments were applied as individual plant treatments (IPT), including 2,4-D (0.5% v/v) + dicamba (0.5% v/v), and glyphosate (1% v/v). Mowing and individual plant removal treatments were also included as well as an untreated control. All treatments were replicated three times. Imazapic (66 g ai ha^{-1}) + metsulfuron (32 g ai ha^{-1}) was applied to ½ of each treatment to compare the effectiveness of this application alone or in combination with other methods. Aminopyralid + metsulfuron, aminopyralid + florpyrauxifen, metsulfuron, and aminocyclopyrachlor treatments provided greater than 90% control of target species at 1.5 and 4 months after treatment (MAT) and prevented the production of any viable seed. Mowing reduced viable seed production (> 70% reduction in flowering plants) if conducted multiple times or at the appropriate timing, but control was low by 4 MAT (<50%). IPT resulted in variable control, providing 76 – 81% control at 1.5 MAT and 12-28% control at 4 MAT. However, IPT did reduce viable seed production to similar levels as in mowing treatments. Including imazapic + metsulfuron suppressed grass height by 44% at 1 MAT and by 34% at 3 MAT, and when applied alone, provided comparable control (>90%) to other high-performing herbicide treatments. Results demonstrate that a range of tools exist to control wild parsnip. Of effective methods demonstrated, imazapic + metsulfuron treatment shows promise as a tool for managers with limited budgets, as it provides effective control of wild parsnip while reducing mowing frequency. This would result in a reduction in ROW vegetation management costs compared to mowing alone.

Cutleaf Vipergrass (*Scorzonera laciniata*) Discovery and Management in Utah. Cody J. Beckley*[1], Jody A. Gale[2], Corey V. Ransom[1], Mark Nelson[3]; [1]Utah State University, Logan, UT, [2]Utah State University Extension, Richfield, UT, [3]Utah State University Extension, Beaver, UT (138)

Cutleaf vipergrass (*Scorzonera laciniata*) is an invasive biennial or perennial forb that can spread rapidly and aggressively in disturbed sites. To date, there is limited information on the total impacted acreage or management options in Utah. Research trials were initiated to evaluate herbicides for cutleaf vipergrass control on rangeland in 2017 and 2018 and on alfalfa in 2017, 2018, and 2019. On rangeland, 2017 treatments consisted of aminopyralid, 2,4-D, chlorsulfuron, imazapic, quinclorac, 2,4-D + triclopyr, and 2,4-D + dicamba. In 2018 treatments were the same as 2017 except for the addition of dicamba, triclopyr, and fluroxypyr applied alone. Treatments were applied to 6 by 18 m plots arranged in a randomized block design, replicated four times. Plots were evaluated for cutleaf vipergrass control and plant density was determined. On alfalfa, 2017 treatments consisted of imazamox, imazethapyr, and 2,4-DB. In 2018 paraquat, carfentrazone-ethyl, saflufenacil, hexazinone, paraquat + hexazinone, and imazamox + 2,4-DB were added to the 2017 treatments. In 2019, glyphosate was added to the 2018 treatment list. Alfalfa plots were evaluated for cutleaf vipergrass control and species biomass. In the 2017 rangeland trial, aminopyralid, chlorsulfuron, 2,4-D + triclopyr, and 2,4-D + dicamba were more effective than untreated for control 60 weeks after treatment (WAT). In the 2018 rangeland trial, aminopyralid, 2,4-D, chlorsulfuron, 2,4-D + triclopyr, and 2,4-D + dicamba were most effective 58 WAT. When considering density counts 58 WAT, aminopyralid, 2,4-D, chlorsulfuron, 2,4-D + triclopyr, and 2,4-D + dicamba treatments provided 75% to 100% reductions in cutleaf vipergrass compared to untreated. Herbicide treatments to alfalfa in 2017 showed minimal cutleaf vipergrass control. In 2018, several treatments caused cutleaf vipergrass injury early, but only imazamox + 2,4-DB was effective 9 WAT, providing 68% control. Imazamox + 2,4-DB provided 71% reduced cutleaf vipergrass biomass compared to untreated. In 2019, Imazamox + 2,4-DB and glyphosate were more effective than all other treatments and untreated 9 WAT, providing up to 71% control of cutleaf vipergrass. Preliminary results from these trials suggest that several herbicides can effectively control cutleaf vipergrass in rangeland settings, while few options exist for control in alfalfa. Growers should be diligent in tracking current infestations to prevent establishment and spread of cutleaf vipergrass until suitable herbicide control options are developed.

Weed Control Spectrum of a Novel Herbicide, Florpyrauxifen-benzyl, for Pastures and Hayfields. Wykle C. Greene*, Michael L. Flessner; Virginia Tech, Blacksburg, VA (579)

Weed control spectrum of a novel herbicide, florpyrauxifen-benzyl, for pastures and hayfieldsW.C. Greene; M.L. FlessnerFlorpyrauxifen-benzyl is a newer group 4, synthetic auxin herbicide in the arylpicolinate herbicide family. A combination of florpyrauxifen-benzyl + 2,4-D, ProClova, has been submitted for registration in pastures and hayfields in the US. Florpyrauxifen-benzyl + 2,4-D reportedly has a level of safety to white clover (*Trifolium repens* L.), allowing broadleaf weed control while preserving white clover. However, there is limited research on the efficacy of florpyrauxifen-benzyl + 2,4-D on common weed species in pastures and hayfields. Several studies were conducted in 2018 and 2019 at several locations in Virginia. Depending on the study, herbicide applications were made either in the spring, summer, or both the fall and spring. All studies used a randomized complete block design with 4 replications. Proclova was applied at a rate of 1.7 L ha^{-1}. Control of the following weed species were evaluated: 1) bulbous buttercup (*Ranunculus bulbosus*), (2) Canada thistle (*Cirsium arvense*), (3) horsenettle (*Solanum carolinense*), (4) mouseear chickweed (*Cerastium fontanum*), and (5) broadleaf plantain (*Plantago major*). All herbicides were applied using a CO_2 pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} at 220 kPa. Visible control ratings were taken on a 0 – 100 % scale, with 0 % being no control and 100 % being complete plant death. All visible injury ratings were subject to ANOVA in JMP Pro and subsequent means separation using Fisher's Protected LSD (a=0.05). Florpyrauxifen-benzyl + 2,4-D provided 97 % and 95 % end-of-season bulbous buttercup control when applied in the fall and spring, respectively. Florpyrauxifen-benzyl + 2,4-D provided 75 % control of Canada thistle control 90 days after treatment (DAT). Horsenettle control from florpyrauxifen-benzyl + 2,4-D was 65 %, 90 DAT. Mouseear chickweed control was 50%, 90 DAT. Florpyrauxifen-benzyl + 2,4-D resulted in 98 % control of broadleaf plaintain control 90 DAT. These data suggest that florpyrauxifen-benzyl is an effective herbicide combination for controlling bulbous buttercup and broadleaf plantain. Florpyrauxifen-benzyl + 2,4-D provided marginal control of Canada thistle, horsenettle, and therefore may not be the best control option for these particular weeds. Future research should include evaluating the control of other common weed species in pastures and hayfields.

WSWS Project 2. Weeds of Horticultural Crops

WSSA Section 2. Horticultural Crops

Seed Treatments for Safening Herbicides in Vegetables. Matthew A. Cutulle[1], Giovanni A. Caputo*[2]; [1]Clemson University, Charleston, SC, [2]Clemson University, Clemson, SC (090)

Weed competition is a limiting factor for growing vegetables. There are limited herbicide products registered in broadleaf vegetable crops, make the management of troublesome weeds, even more complicated. There has been extensive research performed on the development of herbicide safeners for monocot agronomic crops. However, the exploration of compounds that safen broadleaf vegetable crops are insufficient. A strategy to increase the safety of herbicides in leafy greens would be to evaluate novel safener compounds as seed treatments. Brassinosteroids and melatonin could potentially act as herbicide safeners as they activate enzymes involved in metabolism of xenobiotics and/or show an ability to sequester reactive oxygen species. S-metolachlor is an effective herbicide against many broadleaf weeds when applied PRE; however, *S*-metolachlor will cause stunting when applied over the top of direct-seeded leafy greens. A greenhouse experiment, using turnips (*Brassica rapa* L.) and collards (*Brassica oleracea* L.) was conducted to evaluate the ability of Melatonin and 24-Epibrassinolide to reduce injury from *S*-metolachlor. All seed treatments reduce *S*-metolachlor injury relative to seeds that were treated with *S*-metolachlor alone. We found that the use of Melatonin and 24-Epibrassinolide as seed treatments did not cause any negative impact on both crops, and could enhance the herbicide tolerance of turnips and collards to pre-emergence applications of *S*-metolachlor.

Evaluation of Growing Degree Day Based Chemigation Treatments for Management of Branched Broomrape in California Processing Tomato Systems. Matthew J. Fatino*[1], Mohsen B. Mesgaran[1], Brad Hanson[2]; [1]University of California, Davis, Davis, CA, [2]University of California, Davis, Winters, CA (091)

Recent detections of branched broomrape (*Phelipanche ramosa* syn. *Orobanche ramosa*) in California tomato fields warrants the evaluation of herbicide treatment programs to control this regulated noxious weed. Broomrapes *(Phelipanche spp*.) are parasitic weeds that are a severe threat to the California processing tomato industry. A decision support system and herbicide treatment program, known as PICKIT, was developed over two decades of research in Israel, and has provided successful management of Egyptian broomrape (*P. aegyptiaca*) in tomato. The PICKIT system uses a thermal-time model (growing degree days) to forecast the belowground development of the parasite in order to precisely time the application of ALS inhibitor herbicides to target specific life stages of the parasite. Herbicide treatment programs based on the PICKIT system were evaluated in 2019 for crop safety on processing tomato at the UC Davis field facility in two experiments. These treatments included several combinations of preplant incorporated sulfosulfuron applications paired with different rates of imazapic either injected into the drip system or applied as foliar treatments. There were no significant differences in phytotoxicity or yield among herbicide treatments in either the early or late planted experiments and after one field season, the PICKIT decision support system seems to have reasonable crop safety on processing tomato under California conditions. These experiments will be repeated in 2020 at the UC Davis field site. If a commercial site infested with branched broomrape and a cooperating grower is identified, a similar experiment will be conducted in 2020 to evaluate the efficacy of these treatments. Additionally, a rotational crop study was initiated in the 2019 tomato field and will be planted back to crops commonly grown in rotation with tomato in this production region in order to evaluate the potential residual effects of these treatments. Overall, these experiments will generate data necessary to support the registration of these products in California processing tomato if the problem with branched broomrape grows in magnitude.

Effect of Repeated Mechanical Tuber Removal During the Fallow Period on Nutsedge (*Cyperus* spp.) Management in Bell Pepper. Ranjeet S. Randhawa*, Peter J. Dittmar; University of Florida, Gainesville, FL (092)

Nutsedge (*Cyperus* spp.) is labeled as the most troublesome weed for vegetable production. Previous research showed that mechanical tuber removal (MTR) twice during the fallow period; integrated with cover crop and glyphosate is capable to reduce the nutsedge density significantly. However, the effect of repeated mechanical tuber by itself and the timing of MTR on effective season-long control are still unknown. The study objective was to evaluate the appropriate timing and frequency of MTR during the fallow period on nutsedge control during the fall season bell pepper crop. The study consisted of seven treatments and a nontreated check arranged in a randomized complete block design with four replications. The research site was tilled using rotavator at the beginning of the fallow period to initiate uniform nutsedge sprouting. Thereafter, the treatments included 1x MTR at 4 weeks after initiation (WAI) or 16 WAI; 2x at 4+8 WAI or 12+16 WAI; 3x at 4+8+12 WAI or at 8+12+16 WAI; and 4x at 4+8+12+16 WAI. Bell pepper were transplanted at 18 WAI. Data collection during the fallow period was the nutsedge density and tuber counts before each MTR. During the bell pepper season, nutsedge density data were taken at 2-week intervals and at bell pepper harvest weed biomass, tuber counts, total fruit count, and total yield data were measured. The results indicated that at the end of the fallow period the 2x, 3x and 4x MTR had 1 to 3 tubers, which was significantly lower than 9 tubers in non-treated. At 4 weeks after bell pepper transplanting (WAT), all 2x or more MTR treatments had significantly lower nutsedge density relative to non-treated while 3x and 4x MTR had the least density. A similar effect was observed for nutsedge density 8 WAT and at bell pepper harvest. Also, at bell pepper harvest, all treatments with more than one MTR had less than 6 tubers and 5 g of biomass relative to 22 tubers and 13 g of biomass for non-treated. However, no differences in fruit count or pepper yield were observed. This was possibly due to the presence of other weed species as no differences in biomass for other weed species or total weed biomass was observed for any treatment. In conclusion, 2x MTR during the fallow period resulted in significant nutsedge density and tuber reduction relative to non-treated; however, 3x MTR resulted in season-long control and were at par with 4x MTR. Therefore, 3x is obvious to be more economical and could be undertaken at the start of the fallow period or with respect to the fall crop planting date for effective nutsedge management during the fall bell pepper production.

Preliminary Preemergence Herbicide Tolerance Screen for Transplanted Industrial Hemp. Michael L. Flessner*, Kevin W. Bamber, John H. Fike; Virginia Tech, Blacksburg, VA (093)

Industrial hemp (*Cannabis sativa*) has realized a rapid increase in acreage fueled by deregulation and market demand for cannabidiol (CBD) products. However, little is published regarding best production practices including weed control. Herbicides are widely used in other crops, but little is known regarding herbicide tolerance of hemp. The objective of the research was to provide an initial herbicide screening to inform future research efforts, with an overarching goal of supporting herbicide product labelling in transplanted hemp.A study was conducted in Blackstone, VA to evaluate hemp tolerance to various preemergence herbicides. A randomized complete block design with four replications was used. Soil was tilled and bedded as for tobacco production. Plots were a single row and contained 5 plants on 1.5 m spacings and rows were 1.2 m apart. Treatments included: pendimethalin (1.6 kg ha^{-1}), ethalfluralin (1.05 kg ha^{-1}), *S*-metolachlor (1.6 kg ha^{-1}), acetochlor (1.26 kg ha^{-1}), chlorimuron-ethyl (0.035 kg ha^{-1}), fomesafen (0.42 kg ha^{-1}), flumioxazin (0.089 kg ha^{-1}), metribuzin (0.278 kg ha^{-1}), and linuron (1.4 kg ha^{-1}) in addition to a nontreated check. Treatments were applied on May 23, 2019 just prior to transplanting 'BaOx' hemp by hand. Activating rainfall occurred within 24 hours and drip irrigation was provided as needed to prevent drought stress throughout the season. Beds were spot treated with glyphosate as needed to prevent weed competition. Visible injury ratings and stand counts were taken at 13, 25, 40, and 55 days after application. Above ground fresh biomass data were recorded September 24, 2019 as a proxy for yield. All data were subjected to ANOVA followed by means separation using Fisher's protected $LSD_{0.05}$. Pendimethalin was in the least injurious statistical grouping at all rating dates and resulted in less than 10% injury throughout the trial. At the final rating 55 days after application, ethalfluralin, acetochlor, fomesafen, and flumioxazin were in the least injurious statistical grouping and resulted in less than 20% injury. Visible injury symptoms were consistent with herbicide mode of action. Only metribuzin killed hemp transplants and resulted in greater than 90% mortality across rating dates. Less than 15% mortality was observed in the nontreated. The nontreated resulted in 1,300 g $plant^{-1}$ of above ground fresh biomass. Only chlorimuron and metribuzin significantly reduced biomass relative to the nontreated. Pendimethalin was the safest herbicide evaluated. Ethalfluralin, acetochlor, fomesafen, and flumioxazin showed potential for use in transplanted hemp. As this was preliminary research, all herbicides need to be evaluated across more environments and hemp varieties. Future research should also evaluate the potential presence of herbicide residues in hemp flowers or CBD.

Reduced Rates of 2,4-D and Dicamba on Sweetpotato Propagation Beds. Thomas Batts*[1], Stephen C. Smith[2], Levi D. Moore[2], Kira C. Sims[3], Matthew Waldschmidt[2], Sushila Chaudhari[2], Katherine M. Jennings[2]; [1]NC Cooperative Extension, Wilson, NC, [2]North Carolina State University, Raleigh, NC, [3]North Carolina State University, Goldsboro, NC (094)

With the advent of 2,4-D- and dicamba-tolerant crops, some concern exists regarding the potential for drift onto non-target crops including sweetpotato. Thus, a field study was conducted in 2019 to determine the effect of herbicide treatments applied to sweetpotato plant propagation field beds, after which, nonrooted cuttings (slips) from each treatment were cut just above the soil surface and then transplanted to the production field to determine treatment effects on sweetpotato growth, and storage root yield and quality. Herbicide treatments included dicamba alone (0.16, 0.05, 0.025 L ha^{-1}), 2,4-D alone (0.234, 0.073, 0.037 L ha^{-1}), a commercially available premix of 2,4-D + glyphosate (0.556, 0.174, 0.087 L ha^{-1}), and a nontreated control. These treatments were applied at 2 weeks after first cutting (WAFC) of slips or 4 WAFC. Data collected included injury in the propagation beds at 7 and 14 days after each application (DAA), and final root yield. Data were subjected to the mixed procedure in SAS 9.3. When pooled across herbicide rate, the highest rate produced statistically higher injury than the other two rates at both evaluation dates with the exception on dicamba at 14 DAA. Injury from dicamba ranged from 3 to 8% at 7 DAA and 6 to 12% at 14 DAA. Injury from 2,4-D ranged from 7 to 26% at 7 DAA and 9 to 31% at 14 DAA. Injury from 2,4-D + glyphosate ranged from 10 to 29% at 7 DAA and 9 to 39% at 14 DAA. When pooled across herbicide, applications at 2 WAFC, reduced total yield (jumbo + no. 1 + canner) and no. 1 yield, regardless of rate. Total yields ranged from 13.5 kg to 25.2 kg, while no. 1 grade yields ranged from 5.1 kg to 14.39 kg. At 4 WAFC, treatments with the highest herbicide rate across treatments reduced total (10.9 kg), canner (3.6 kg), and no. 1 (4.1 kg) yield. When pooled across herbicide rates, dicamba applied 2WAFC resulted in lower total (9.3 kg), jumbo (1.08 kg), and no. 1 (3.6 kg) yield when compared to the nontreated control. Applications made 4 WAFC application only resulted in a reduction in no. 1 yield, regardless of the treatment.

Protecting Specialty Crops from Pests – How the Western Region IR-4 Project Helps Meet Farmer Pest Control Needs. Michael J. Horak*[1], Stephen Flanagan[2], Mika Tolson[1]; [1]Western Region IR-4 Project, University of California, Davis, Davis, CA, [2]Western Region IR-4 Project, University of California, Davis, Eugene, OR (095)

Since 1963 the IR-4 Project has been the primary resource for facilitating registrations of conventional chemical pesticides and biopesticides for specialty crops and other minor uses in the United States. Using its unique ability to partner with government, industry and farmers, IR-4 develops required data to support registration of pest management products. IR-4 is funded through a grant from the US Department of Agriculture – National Institute of Food and Agriculture, through in-kind support from land grant universities, and support from other organizations. The California Department of Food and Agricultural also provides funding for projects of specific interest to California farmers. IR-4's aim is to provide safe and effective pest management solutions for specialty crop farmers. There are three component programs of the overall IR-4 Project including a) Food Use (residue, efficacy and crop safety); b) Integrated Solutions (organic support, resistance management, residue mitigation, and screening); and c) Environmental Horticulture (efficacy and crop safety). The Western Region IR-4 office located at University of California, Davis represents western state stakeholders. The office seeks to identify, nominate and secure support for projects of interest to western state specialty crop growers. The project process includes multiple steps: A) Needs (pest, crop and potential pesticide) are identified through stakeholder awareness and outreach; B) A formal project request is made through an online portal (www.ir4project.org); C) Projects are prioritized at the regional and national level; D) Field research is conducted to generate needed efficacy and crop safety data and EPA required samples for residue testing; Laboratory analysis is conducted for residue testing; E) A petition is developed and provided to the EPA; F) The EPA reviews the data and approves (or not) a new tolerance; G) The manufacturer adds the new crop or new use to an existing product label; H) Specialty crop farmers gain access to a new tool for use in protecting their crop. mjhorak@ucdavis.edu

Suppression of Hazelnut (*Corylus avellana*) Suckers with 1-Naphthylacetic Acid. Arnaldo Marques Caldera da Silva[1], David R. King*[2], Richard K. Zollinger[3], Marcelo L. Moretti[2];

[1]University of São Paulo, Piracicaba, Brazil, [2]Oregon State University, Corvallis, OR, [3]Amvac Chemical Company, Spokane, WA (096)

Sucker management in hazelnut is a labor-intensive practice. Removal of suckers increases yield and facilitate mechanization, and is common in the United States, but requires multiple herbicide applications. Sucker growth is vigorous and continuous during the spring and summer season. This study investigated the use of 1-naphthylacetic acid (NAA), a plant growth regulator, to suppress hazelnut sucker growth. Field studies were conducted in non-bearing hazelnut orchards located in Western Oregon. Suckers were treated with NAA at 1.4, 2.8, or 5.6 kg ai ha^{-1} in April 2019. A sequential application of NAA (2.8 kg ai ha^{-1}) at 0 and 28 days after treatments (DAT), a nontreated control, and 2,4-D (1.07 kg ai ha^{-1}) were included. Suckers treated with NAA and 2,4-D were, on average, 57% smaller than untreated suckers with a height ranging from 25 to 36 cm. The sequential application of NAA suppressed sucker growth by up to 90 DAT with treated suckers 40 to 70% smaller than the untreated (33 to 70 cm height). The data show that NAA can effectively reduce hazelnut sucker growth and can be an effective new tool in the chemical pruning of suckers.

Evaluation of Herbicide Programs in Dormant Stevia (*Stevia rebaudiana*) in North Carolina.
Robert M. Welker*[1], Roger B. Batts[2]; [1]North Carolina State University, Raleigh, NC, [2]NCSU IR-4 Field Research Center, Fremont, NC (097)

Stevia (*Stevia rebaudiana*) is an emerging crop in NC and the Southeast US with much grower interest and industry support. Since stevia will be a perennial crop, winter weed control is critical in order to keep stevia from being at a competitive disadvantage to weeds when it emerges in the Spring. Three separate studies were conducted to evaluate chemical weed control strategies in dormant stevia. Each of the studies consisted of four trials. These were conducted at the Caswell Research Farm, Kinston NC in 2017, Border Belt Tobacco Research Station, Whiteville, NC in 2018, Upper Costal Plane Research Station, Rocky Mount, NC in 2018 and the Horticultural Crops Research Station, Clinton, NC in 2019. All were set up as a randomized complete block design with either 3 or 4 replications. Percent weed control of winter annuals compared to a control were assessed as well as injury to the stevia growth in the Spring. Study 1. Evaluation of Linuron and Flumioxazin in Dormant Stevia. Two applications of each treatment were made to the same plots; once in mid-December and once in mid-January. Treatments (g ai ha ⁻1): 1. Linuron (841) + Paraquat dichloride (841) + NIS 2. Linuron (841) + Paraquat dichloride (841) + Oxyfluorfen (280) + NIS 3. Linuron (1121) + Paraquat dichloride (841) + NIS 4. Linuron (1121) + Paraquat dichloride (841) + Oxyfluorfen (280) + NIS 5. Flumioxazin (71) + Paraquat dichloride (841) + NIS 6. Flumioxazin (71) + Paraquat dichloride (841) + Oxyfluorfen (280) + NIS 7. Linuron (841) + Flumioxazin (71) + Paraquat dichloride (841) + NIS 8. Linuron (1121) + Flumioxazin (71) + Paraquat dichloride (841) + NIS Greater than 96% overall weed control was seen for all treatments at all locations by Spring emergence of Stevia and no injury to the crop was noted. Study 2. Terbacil Evaluation in Dormant Stevia. Two different rates of terbacil were applied mid-December or mid-January. Treatments (g ai ha ⁻1): 1. Terbacil (897) + NIS, mid-December 2. Terbacil (1795) + NIS, mid-December 3. Terbacil (897) + NIS, mid-January 4. Terbacil (1795) + NIS, mid-January Overall weed control for the December only applications had dropped to between 75 and 85% for all locations by Spring emergence of stevia. January applications provided better overall weed control (94 to 97%) at all locations. Again, no injury was noted on the emerging Stevia in this study. Study 3. Stevia Response to Indaziflam Applied in Winter. Indaziflam was applied at two rates in mid-December or mid-January. Treatments (g ai ha $^{-}$1): 1. Indaziflam (51) + Paraquat dichloride (841) + NIS, mid-December 2. Indaziflam (102) + Paraquat dichloride (841) + NIS, mid-December 3. Indaziflam (51) + Paraquat dichloride (841) + NIS, mid-December fb Indaziflam (51) + Paraquat dichloride (841) + NIS, mid-January 4. Indaziflam (51) + Paraquat dichloride (841) + NIS, mid-January 5. Indaziflam (102) + Paraquat dichloride (841) + NIS, mid-January January applications provided overall weed control of 85% or better at all locations, while December applications averaged better than 91% at all locations. Sequential applications at 51 g ai ha^{-}1 provided overall weed control of 97% by emergence of the stevia in the Spring. No injury to the emerging Stevia crop was noted in this study. Results suggest several potential strategies for control of winter weeds in stevia, allowing good rotational use of herbicides by growers in North Carolina and the Southeast.

Crabgrass Control with Tembotrione, Topramezone, and Tolpyralate in Sweet Corn. Ed Peachey*; Oregon State University, Corvallis, OR (098)

Tembotrione, topramezone, and tolpyralate effectively control many summer annual grasses in sweet corn when tank mixed with atrazine, even at low atrazine rates. Crabgrass and common purslane are tolerant to these Group 27 herbicides if atrazine is not used. Removing atrazine from Group 27 tankmixes is essential if planning to interseed cover crops. Tankmixing these herbicides with carfentrazone and bentazon improves purslane, pigweed, and common lambsquarters control, but the effect on crabgrass control is unknown. Sweet corn (SH2, Var. Driver) was planted on 23-May, 2019 on a silt loam soil into 3 by 7.6 m plots with 3 replications. Herbicides were applied to V4 corn on 21-Jun. Crabgrass control with tolpyralate was slightly better than tembotrione and topramezone when applied with methylated seed oil and urea ammonium nitrate adjuvants. Tembotrione and tolpyralate controlled crabgrass equally when tankmixed with carfentrazone or bentazon and crop oil concentrate (COC) was included as the adjuvant. Crabgrass control was very poor when topramezone was tankmixed with carfentrazone or bentazon and applied with COC. It is unclear whether this difference was due to an antagonism between the tank mixed herbicides or the adjuvant used with this tankmix. Tankmixes with bentazon caused less injury than tankmixes with carfentrazone. Tolpyralate tankmixed with bentazon yielded 15.1 mt ha^{-1} with no indication of crop injury and 78% control of crabgrass at harvest.

Yield Loss Estimates for Vegetables in the USA and Canada. Mark VanGessel*[1], Nicholas T. Basinger[2], Ian Burke[3], Anita Dille[4], Wesley Everman[5], Michael L. Flessner[6], Zahoor A. Ganie[7], Sandeep S. Rana[8], Scott Senseman[9], Peter H. Sikkema[10], Nader Soltani[10]; [1]University of Delaware, Georgetown, DE, [2]University of Georgia, Athens, GA, [3]Washington State University, Pullman, WA, [4]Kansas State University, Manhattan, KS, [5]North Carolina State University, Raleigh, NC, [6]Virginia Tech, Blacksburg, VA, [7]FMC, Newark, DE, [8]Bayer Crop Science, Galena, MD, [9]The University of Tennessee, Knoxville, TN, [10]University of Guelph, Ridgetown, ON, Canada (099)

Abstract not available

IR-4 Project Update and Program Changes. Daniel Kunkel*[1], Roger B. Batts[2], Jerry Baron[3], Michael J. Braverman[4]; [1]IR-4 Project, Rutgers University, Princeton, NJ, [2]NCSU IR-4 Field

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The USDA-NIFA, IR-4 Project continues to successfully address pest control needs for specialty crop growers. In 2019, EPA approved more than 1,600 new uses based on IR-4 research. Nearly thirty percent of these new uses (over 450) included herbicide label expansions on products such as trifluralin, S-metolachlor, bentazon, pyraflufen-ethyl, indaziflam, pendimethalin and others. New registrations and new uses were obtained that provide enhanced pest control in a broad range of specialty crops including tropical fruits, herbs and spices, leafy vegetables, root vegetables, tree fruits and others. IR-4 expects a similar number of approvals for 2020 with several submissions pending at EPA including products such as saflufenacil, clopyralid, pronamide, isoxaben, and quizalofop. There are also several projects that will be submitted to EPA in the coming months and other projects in progress that are intended to support future submissions. The IR-4 2020 herbicide residue and crop safety work will account for over 30% of IR-4 research program. In 2018, IR-4 initiated a new program to better serve the needs of the IR-4 stakeholders. This program, entitled Integrated Solutions (IS) Research Program, is designed to address pest problems without solutions, resistance management, products for organic production and pesticide residue mitigation. IS projects relating to weed control include: addressing the growing problem of Branched broomrape (*Orobanche ramose*, aka *Phelipanche ramose*) control in tomato, screening herbicides for organic weed control and weed control in brassica vegetables. The need for IR-4 to develop product performance data (efficacy and crop safety research) to support labeling of new uses for specialty crop pest management tools continues to be an important priority in the IR-4 Project's annual research plan as the data are often required by registrants and states (e.g.California) to complete the registration process. IR-4 Headquarters will be relocating over the next two years to a new host institution, NC State's College of Agriculture and Life Sciences. This move will ensure the long-term viability of The IR-4 Project with strong strategic alignment to that of the NC State College of Agriculture and Life Sciences' regulatory sciences and agriculture research programs.

Influence of Hemp Variety and Weed Free Period on Yield in Coastal South Carolina. Harrison T. Campbell*, Matthew A. Cutulle; Clemson University, Charleston, SC (101)

With 114 licensed growers in South Carolina, hemp is becoming more agriculturally significant across the state. Little research has been conducted exploring the impact of weed competition on hemp grown in South Carolina. A field experiment was conducted in 2019 to assess yields of 6 hemp varieties commonly grown in South Carolina (Cherry Wine, Hurricane, Cherry Blossom, Therapy, T1, and Boax) when kept weed free for various periods of time (0, 1, 2, 4, and 6 weeks). The trial was designed as a randomized complete block with three replications. Weeding was achieved by manually hoeing around each plant approximately 3 feet from the base of the stem. The row middles, consisting mostly of grasses, were mowed once per week. Dry bud weights for each variety were significantly greater after one weed free week compared to the non-weeded plots across all varieties, with the exception of Therapy. Variety Therapy had the lowest dry bud weights for each weed free period across all varieties, including the non-weeded check. No significant differences in dry bud weights were observed for any of the 6 varieties between 1-week weed free and 6 weeks weed free, while four of the varieties achieved peak dry bud yields between 2-4 weeks weed free (Boax, Cherry Blossom, Cherry Wine, and T1).

Can a Sunn Hemp (*Crotalaria juncea*) Living Mulch Reduce Herbicide Usage in Sweet Corn?
Robert E. Nurse*[1], Jichul Bae[2], Kerry Bosveld[1], Marie-Josee Simard[3]; [1]Agriculture and Agri-Food Canada, Harrow, ON, Canada, [2]Agriculture and Agri-Food Canada, Agassiz, BC, Canada, [3]Agriculture and Agri-Food Canada, Saint-jean-sur-richelieu, Canada (102)

Sweet corn producers have fewer registered herbicides available in comparison to field corn producers. Therefore, it is important to develop weed management systems that address the stewardship of these products. The use of living mulches within a sweet corn crop can potentially improve weed control and reduce the over reliance on herbicides. The objective of this research was to evaluate the weed control provided by Sunn hemp in combination with full or reduced herbicide doses. The trial was conducted at three locations across Canada (Agassiz, BC., Harrow, ON., and St. Jean-sur-Richelieu, QC.) in 2018 and 2019. The trials were arranged as split plot designs with the main plot being the presence or absence of the living mulch and the sub-plot being herbicide dose. A half dose of saflufenacil/dimethenamid-P (0.368 kg ai/ha) was applied pre-emergence over the entire trial to provide initial grass and broadleaved weed control. The sub-plot treatment of mesotrione + Agral 90 was applied at 100 (0.1 kg ai ha^{-1} + 0.2% v/v), 75, 50, 25, and 0% doses. Mesotrione caused bleaching (up to 62%) in the Sunn hemp that persisted for more than 42 days after application, and reduced biomass (up to 80%) in comparison to the untreated control. The most effective weed biomass reductions were obtained when Sunn hemp was present; however, there was no significant effect of herbicide dose. Sweet corn height, stand, and time to 50% tassel was not affected by the presence of the living mulch or dose of the herbicide. Similarly sweet corn yield was not affected by either factor in comparison to the weed-free control. Results demonstrated that herbicide dose could be reduced when paired with Sunn hemp in a sweet corn crop.

Update on Herbicide Resistance Genetic Testing. Kristen A. Obeid[1], Marie-Josee Simard[2], Martin Laforest[3], Robert E. Nurse*[1], Eric R. Page[1], David Miville[4]; [1]Agriculture and Agri-Food Canada, Harrow, ON, Canada, [2]Agriculture and Agri-Food Canada, Saint-jean-sur-richelieu, Canada, [3]AAC-AAFC, St-jean-sur-richelieu, QC, Canada, [4]MAPAQ, Quebec City, QC, Canada (103)

Herbicide resistant weed biotypes were surveyed in horticulture crops in Ontario and Québec to develop and trial diagnostic tests based on molecular markers. Herbicide resistant populations must be detected and managed rapidly in high value crops such as carrots, grapes, onions, strawberries and tomatoes where fewer herbicide options are available. Diagnostic tests based on molecular makers offer rapid results compared to conventional greenhouse evaluations. Since 2016 a total of 76 cases of herbicide resistance have been reported and a total of 16 genetic (five more in progress) and two species differentiation tests have been successfully developed. In 2019, these tests detected multiple resistance cases (ALS + Photosystem II inhibitors) in green pigweed (*Amaranthus powelii*) in three tomato fields. Different common ragweed (*Ambrosia artemisiifolia*) plants in the same carrot field were also resistant to either ALS or Photosystem II inhibitors.

Overall, 71% of the weed biotypes surveyed tested positive for genetic mutations conferring resistance.

Grape Response to Simulated Drift of Auxin Herbicides. Steven C. Haring*[1], Junjun Ou[2], Kassim Al-Khatib[1], Brad Hanson[3]; [1]University of California, Davis, Davis, CA, [2]Corteva Agriscience, Indianapolis, IN, [3]University of California, Davis, Winters, CA (104)

Grapes are the most valuable crop and the second most extensively grown horticultural crops in California, and they are highly susceptible to injury from auxinic herbicides. Winegrape growers are concerned about the potential impact of auxinic herbicide drift, given the high economic value of their crop and renewed public concerns about auxinic herbicides at the national level. Our objective was to compare the relative sensitivity of winegrapes to simulated auxinic herbicide drift, including symptomology, harvest yield, and harvest quality. In a randomized complete block design with three replications, we applied four herbicides at four simulated drift rates to one side of one vine row in a vineyard in Davis, CA. Plots were two vines long separated by one vine, and the vines were mature Grenache trained to a two-wire vertical trellis. Treatments were applied with a two-nozzle spray boom calibrated to spray 187 l ha^{-1}. We applied 1/900, 1/300, 1/100, and 1/33 of a recommended field rate of each 2,4-D, aminopyralid, dicamba, and triclopyr; fractional rates were based on full field rates of 1454 g ae ha^{-1}, 122.5 g ae ha^{-1}, 280 g ae ha^{-1}, and 2240 g ae ha^{-1}, respectively. Treatments were applied around the time of fruit set, on June 13, 2018 and again on June 11, 2019. Each year, the vines were monitored for visible injury and harvested when berries in nontreated plots reached approximately 20^{o}Bx (a measure of dissolved solids that is directly correlated with sugar content), which occurred in late August each year. Visible injury symptoms included tendril and apical death, leaf malformations such as leaf cupping, and inconsistent veraison (ripening) and were observed in all simulated drift treatments from seven to 56 days after application. In 2019, only the 1/100X and 1/33X rates of triclopyr resulted in greater than 10% visible injury through the observation period. Additionally, greater than 10% injury was observed with the 1/300X rate of triclopyr between seven and 28 days after treatment and with the 1/33 rate of dicamba at 14 days after treatment. In both years of the study, the 1/100X and 1/33X rates of triclopyr were the only treatments to result in yield reduction. Additionally, these treatments increased Brix in 2018 and the 1/33X rate increased Brix again in 2019. While the grapes in this study consistently displayed injury from simulated auxinic herbicide drift, only the highest rates of triclopyr used in this study reduced harvest yield and quality. There is an indirect link between injury symptoms and harvest damage, and crop injury was generally less severe than we had expected. Importantly, this research does not study how herbicide drift could affect more complex components of winegrape quality, such as anthocyanin content. Future research should more fully examine the economic impact of auxinic herbicide drift on wine grapes and whether this type of exposure can lead to herbicide residues in fruit at harvest that are above regulatory thresholds.

On-Farm Evaluation of POST-Directed Flumioxazin in New Mexico Chile Pepper. Brian J. Schutte*; New Mexico State University, Las Cruces, NM (105)

We previously determined that POST-directed, row middle applications of flumioxazin at 70 g ai ha^{-1} and 107 g ai ha^{-1} did not cause visual symptoms of herbicide injury and fruit yield loss in chile pepper. Considering these results, we developed draft recommendations for a new herbicide in

New Mexico chile pepper production. In this study, we tested our draft recommendations in commercial chile pepper fields. Our objectives were: (1) assess POST-directed, row middle applications of flumioxazin for weed control in chile pepper, (2) measure chile pepper fruit yield responses to POST-directed, row middle applications of flumioxazin, and (3) determine if POST-directed, row middle applications of flumioxazin result in chile pepper fruits with residues greater than U.S. federal tolerances. To address these objectives, POST-directed applications of flumioxazin were studied in a commercial field in 2018 and 2019. In 2018, flumioxazin at 35 and 70 g ai ha^{-1} was applied with a tractor-mounted, hooded sprayer. In 2019, flumioxazin at 70 and 107 g ai ha^{-1} was applied with a CO_2-powered backpack sprayer equipped with a hooded nozzle. At the time of application, chile plant height was 40-45 cm in 2018, 30-40 cm in 2019. Chile pepper fruits were harvested 45 d after spraying in 2018, 37 d after spraying in 2019. Results indicated that POST-directed applications of flumioxazin (1) provided at least 4 weeks of control on weeds including Palmer amaranth, Wright groundcherry, Russian thistle and spurred anoda, (2) did not reduce chile pepper fruit yield, and (3) did not result in chile pepper fruits with flumioxazin residues. These results are additional information supporting a Special Local Need (SLN) registration for POST-directed flumioxazin in New Mexico chile pepper. Pending SLN registration, flumioxazin is expected to provide farmers new opportunities to reduce expenses in chile pepper production.

Have Greenhouse - Will Conduct Bioassays: A Grower Asked and We Rode to the Rescue. Pamela J.S. Hutchinson*, Celestina S. Miera, Brenda C. Kendall, Tenika Trevino, Brent R. Beutler; University of Idaho, Aberdeen, ID (106)

In 2019, a grower in southern Idaho inadvertently applied two times the desired rate of 2 pt/A Boundary (s-metolachlor + metribuzin) + 1 pt/A Linex (linuron) to four potato fields. The error was realized before the grower moved to other fields because herbicides originally purchased were used up too soon and the sales records were reviewed. Potato plants growing in the four fields in 2019 did not exhibit visual injury during the spring and summer and tuber yields and quality were not affected detrimentally. Sugar beet was to be grown in all four fields the following year, 2020. Upon request from the grower, the University of Idaho Potato Cropping Systems Project agreed to conduct a greenhouse sugar beet bioassay at the UI Aberdeen Research and Extension Center with soil collected from the fields of interest. At risk was the grower's expected return on the dollar invested in producing sugar beet in those fields in 2020 if the herbicide concentration level was high enough to cause sugar beet crop injury and subsequent yield loss. Within two weeks after potato harvest mid-September 2019, the grower collected soil to a 6-inch depth in multiple, random locations in each field for an initial bioassay. Samples within a field were combined. In general, all fields had a Declo loam soil with pH 8.0 to 8.1 and O.M. 1.1 to 1.4%. A field with similar soil but where herbicides not detrimental to sugar beet had been applied in 2018 and 2019 was sampled for use as a control. Flats 24 in wide x 36 in long x 3 in deep were filled with soil 2 inches deep. Four flats, i.e. four reps for each field were created. Sugar beet seed the same variety to be used by the grower in 2020 was planted in four rows, 12 seeds per row. In- and between-row spacing was 2 inches. Planting depth was 0.25 inches deep – enough soil to completely cover the seed. Flats were watered twice daily. Sugar beet plants began to emerge 8 to 10 days after planting. Plant emergence ranged from 90 to 95% and emergence in suspect field soil was not different than emergence in control soil. However, between three and four days after emergence, 85 to 95% of plants in all flats except the controls, died or were dying. One month after the first bioassay, soil again was collected and a second bioassay using the same protocol as the first was conducted. Result of the second bioassay were similar to results of the first bioassay. Soil samples from each flat in the second bioassay were collected ten days after emergence. Samples from flats for the same field were combined and analyzed for herbicide presence and concentration. Soil from all four suspect fields had s-metolachlor and concentration ranged from 0.075 to 0.2 ppm. One field also had metribuzin at 0.017 ppm, and the other two fields had metribuzin at 0.031 and 0.01 ppm and linuron at 0.01 and 0.011 ppm. Plant symptoms when only s-metolachlor was present were somewhat twisted green cotyl with the first true leaf dead/not present. When metribuzin also was present, some plants had green cotyl and a dead first leaf, but the majority of the plants only had black, burnt stems remaining. Plants in the soil with all three herbicides had only burnt, black stems, or brown, desiccated cotyl and first leaf. Germinating and emerging sugar beet plants rely on the seed until roots begin to develop and take up nutrients and moisture from the soil. Uptake through roots of shallow-planted sugar beet is reported to start occurring 2 to 3 days after emergence. Sugar beet plant emergence in suspect field soil was not different than emergence from control soil in both of our bioassays, but then a high percent of plants in suspect field soil died 3 to 4 days after emergence. This phenomenon was likely due to plants not having enough roots to absorb herbicides from the herbicide-contaminated soil until two to three days after emergence. In addition, metribuzin and linuron are photosynthetic inhibitors requiring light to activate which may explain why plants in soil which had linuron and/or metribuzin at first emerged but then were burnt black or brown and desiccated. After seeing the bioassay results, the grower decided not to plant sugar beet in any of the four fields. Since the sugar beet acres are under contract, having the results by two months after potato harvest is allowing the grower time to look for alternative fields for 2020. The grower reported to us that a loss of more than $150,000 would have occurred had sugar beet been planted in the four fields.

WSWS Project 3. Weeds of Agronomic Crops

WSSA Section 1. Agronomic Crops

Wheat Variety Tolerance to Metribuzin and Pyroxasulfone. Lane S. Newlin*, Misha R. Manuchehri, Brett F. Carver, Amanda De Oliveira Silva, Hannah C. Lindell, Justin T. Childers; Oklahoma State University, Stillwater, OK (001)

Metribuzin is a herbicide that is still widely used in cropping systems annually. However, its use in winter wheat in Oklahoma has declined due to varietal sensitivity or lack of information regarding the topic. To evaluate modern winter wheat varieties, a trial was conducted at Dacoma, Fort Cobb, Goodwell, and Perkins, Oklahoma in the fall of 2019. Treatments consisted of two herbicide mixtures and a nontreated control. Mixtures included pyroxasulfone at 119 g ai ha^{-1} plus 105 or 210 g ai ha^{-1} of metribuzin. Herbicide mixtures were applied PRE and delayed PRE (wheat spike). Visual wheat response was recorded every two to three weeks after the first application. Six weeks after application at the Fort Cobb and Perkins locations, biomass from one meter of row was clipped at the soil surface, dried, and recorded. For biomass at Fort Cobb, there was an application timing by metribuzin rate interaction where biomass at the PRE timing was 40 and 74% less than the nontreated control following metribuzin at 105 and 210 g ai ha^{-1}, respectively. At the delayed PRE timing, biomass was similar following both rates but was reduced by approximately 31% compared to the nontreated control. For biomass at Perkins, there was a metribuzin rate effect where biomass decreased by 42% and 70% compared to the nontreated control following metribuzin at 105 and 210 g ai ha^{-1}, respectively. Results suggest that variety, application timing, and metribuzin rate will continue to be important when using this herbicide in wheat. lane.newlin@okstate.edu

Overlapping Residual Herbicides for Control of Glyphosate-Resistant Palmer Amaranth in Dicamba/Glyphosate-Resistant Soybean. Shawn T. McDonald*[1], Prashant Jha[2], Amit J. Jhala[1];[1]University of Nebraska-Lincoln, Lincoln, NE, [2]Iowa State University, Ames, IA (002)

Palmer amaranth emerges throughout the growing season; therefore, a single application of a residual PRE herbicide may not provide season-long control in soybean. The evolution of glyphosate and ALS-inhibitor-resistant Palmer amaranth in Nebraska makes it difficult to manage. An experiment was conducted in a grower's field infested with glyphosate/ALS-inhibitor-resistant Palmer amaranth in 2018 and 2019 to evaluate the effect of soil residual PRE followed by (fb) a tank-mixture of foliar active and residual POST herbicide programs in dicamba/glyphosate-resistant soybean. Treatments were arranged in a randomized complete block design with four replications and included a weed-free and non-treated control. At 14 d after PRE (DAPRE), flumioxazin/pyroxasulfone, flumioxazin/pyroxasulfone/chlorimuron, flumioxazin/pyroxasulfone/metribuzin, and flumioxazin/chlorimuron provided 63 to 99% control in 2018 and 85 to 95% control in 2019. Programs containing PRE fb POST of dicamba or acetochlor + dicamba controlled Palmer amaranth 73 to 96% in 2018 and 98 to 99% in 2019 at 14 d after POST (DAPOST). Similarly, PRE fb POST applications of dicamba or acetochlor + dicamba had Palmer amaranth density reductions of 77 to 99% (2018) and 100% (2019) at 14 DAPOST. At 42 DAPOST, PRE fb dicamba or PRE fb acetochlor + dicamba did not show any difference in Palmer amaranth control in 2019 (98 to 99%). Herbicide programs had no effect on soybean seed yield. This study concludes that overlapping residual herbicide programs can be effective at managing multiple herbicide-resistant Palmer amaranth in dicamba-resistant soybean.

Interference of *Amaramthus palmeri* in Sugar Beet. Whitney R. Schultz*, Nevin Lawrence; University of Nebraska-Lincoln, Scottsbluff, NE (003)

Glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) is becoming common in the High Plains sugar beet (*Beta vulgaris*) production region. There are no effective PRE or POST herbicide options in sugar beet for Palmer amaranth control. The competitive ability of Palmer amaranth in sugar beet has not been previously quantified. Therefore, a two-year study was carried out in Scottsbluff, NE to measure the impact of season-long Palmer amaranth competition in sugar beet, and to provide information on expected weed production from uncontrolled Palmer amaranth. Palmer amaranth densities were 0, 0.5, 1, 2, 4, and 8 plants m row^{-1} in 2018 and 0, 0.2, 0.3, 0.5, 1, and 2 plants m row^{-1} in 2019. Response variables included sugar beet yield loss, Palmer amaranth seed production plant^{-1} and seed production m^{-2}. Using the R package 'DRC', a four-parameter log-

logistic model was used to estimate Palmer amaranth seed production and a three-parameter Michaelis-Menten model was used to estimate sugar beet yield loss. The estimated density to cause 50% yield loss was 0.06 and 0.2 plants m row^{-1}, depending on year. Seed production plant^{-1} ranged from 37,500 to 355,000, and from 61,900 to 250,000, depending on weed density, in 2018 and 2019, respectively. Seed production m^{-2} was as high as 1,850,000 and 402,000, depending on year. Both Palmer amaranth seed production and sugar beet yield were impacted by hail storms in 2019. The study will be repeated in 2020.

Soybean Response to Aminopyralid, Dicamba, 2,4-D and Aminocyclopyrachlor Applicatioin. Trey I. Clark*[1], Thomas C. Mueller[1], Larry Steckel[2]; [1]University of Tennessee, Knoxville, TN, [2]University of Tennessee, Jackson, TN (004)

This research compared the visual symptomology of four auxin herbicides applied at three rates to simulate tank contamination on non-dicamba tolerant soybeans. The herbicides were aminocyclopyrachlor (ACP), 2,4-D, dicamba, and aminopyralid; the standard labeled rates (SLR) used to base the application rates were 0.11, 1.17, 1.12, and 0.12 kg ae/ha respectively. These four herbicides exhibit similar symptoms on soybeans which is problematic when diagnosing soybean response. One goal of this project was to obtain high-quality images of the four herbicide's effect on soybeans, with the hope of being able to discern the herbicides solely from visual symptoms. Each herbicide was applied at three different rates: 0.1X, 0.01X, and 0.001X of the SLR. The application was made at the R1 soybean stage. A randomized complete block design with three replications was utilized. Border rows for each plot were inspected for injury to assess potential drift between plots. The plots were visually evaluated for herbicide response at 3, 7, 14, and 21 days after treatment (DAT). Two trifoliate leaves were collected during each evaluation for future chemical analysis (data not shown). At 21 DAT, all 0.1X treatments had greater than 20% crop injury. The 0.001X rate for each herbicide exhibited different symptomology when compared to 0.1X rate. Leaf cupping and galls were more prominent on soybeans at lower herbicide dosages. Increasing the herbicide dosage changed symptomology from leaf cupping and galls to necrosis, leaf curling, and epinasty. There were no profoundly distinct visual differences between herbicides. Soybean yield and herbicide dosage were inversely related, and each herbicide affected soybeans differently. No 2,4-D treatments reduced yield. Dicamba at 0.001X reduced soybean yield 19%. Aminopyralid and ACP at 0.01X reduced soybean yields 43% and 16%, respectively. Future research will determine the herbicide concentrations in the leaves and relate them to crop response.

Herbicide Application Associated with Varying Planting Dates in Oklahoma Soybean Production. Sarah E. Kezar*, Josh Lofton, Misha R. Manuchehri; Oklahoma State University, Stillwater, OK (005)

Management of weeds in Oklahoma soybean production fields is one of the greatest challenges facing Oklahoma producers, coupled with continued emergence of herbicide resistant weeds. With that, understanding how cultural management practices, such as planting date, can alter best management practices for weed control will be critical. A trial was conducted from 2016 to 2018 to evaluate herbicide programs following three soybean planting dates at the Mingo Valley Research Station in Bixby, Oklahoma. The three plating dates were April (Early), mid-May

(Delayed), and mid-June (Late). Preemergence herbicide treatments were applied as a tank-mix of pyroxasulfone, glyphosate, and dicamba. All in-season herbicide applications at 3 and 6 weeks after planting (WAP) included glyphosate and dicamba. Prior to postemergence applications at 3 and 6 WAP, visual estimations assessed percent weed coverage between rows. At harvest, crop yield and final percent weed coverage ratings were evaluated. Indifferent of planting date or year, pairing preemergence treatments with in-season, postemergence applications resulted in fewer weeds and higher soybean yields. In fact, omitting a preemergence herbicide application resulted in a 10-15% greater loss in yield and 5% less weed control compared to earlier planted soybean coupled with a preemergence. Use of preemergence herbicides merited higher yields and increased weed control, which even held true with late-planted soybean. Results support how critical preemergence herbicides are for soybean production, especially in late-planted or double-crop settings where less vegetative biomass production is expected. Crop competition strategies of planting date are cultural control options that can fit both production and weed management goals.

Interactions of Dicamba, Glyphosate, and Glufosinate as Tank-Mix Partners. Adam L. Constine*, Christy Sprague; Michigan State University, East Lansing, MI (006)

Herbicide-resistant weeds, such as Palmer amaranth (*Amaranthus palmeri* S. Wats) and common waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer), continue to present challenges for growers across the United States. The increasing occurrence of herbicide resistance in these two species, paired with their rapid growth habits, extended emergence, and prolific seed production have caused them to become two of the most troublesome weed species in production agriculture. New crop technology platforms, such as Bayer's XtendFlex® trait system, provide growers the flexibility to use multiple effective herbicide sites of action for the control of herbicide-resistant weeds in cotton (*Gossypium hirsutum*) and soybean (*Glycine max*). The XtendFlex® trait system confers resistance to three herbicides with differing sites of action, including: glyphosate (WSSA group 9), glufosinate (WSSA group 10), and dicamba (WSSA group 4). The objective of this research was to understand how these herbicides interact when tank-mixed with one another and how these tank-mixtures can influence the control of glyphosate-resistant (GR) Palmer amaranth and common waterhemp. A field experiment was conducted at a GR waterhemp site in Shepherd, MI in 2019 and greenhouse experiments were conducted examining control of GR waterhemp and Palmer amaranth at Michigan State University in East Lansing, MI. In the field, GR waterhemp was sprayed in the absence of a crop when the plants were 10-15 cm tall and at the 5-7 leaf stage. Glyphosate (1.3 kg ae ha^{-1}), glufosinate (0.65 kg ha^{-1}), and dicamba (0.56 kg ha^{-1}) were applied alone, in combination with another, and in a three-way mix. Applications of glyphosate and dicamba provided 40% and 74% waterhemp control, respectively, 14 days after treatment (DAT). Whereas tank-mixtures of these two herbicides provided 88% control. Colby's analysis of aboveground waterhemp biomass from two 0.25 m^2 quadrats per plot indicated that tank-mixtures of glyphosate + dicamba and glyphosate + glufosinate + dicamba were additive, while the combinations of glyphosate + glufosinate ($p = 0.042$) and glufosinate + dicamba ($p = 0.064$) were antagonistic. The results of this research suggest growers may see a reduction in waterhemp control when tank-mixing

Boll Opening Efficacy as Influenced by Cotton Maturity. Cayden B. Catlin*, Bradley R. Wilson, Seth A. Byrd; Oklahoma State University, Stillwater, OK (007)

Applications of harvest aids in cotton are recommended to occur when there are 4 nodes between the uppermost first position cracked boll to uppermost first position harvestable boll (NACB). However, most of the recommendations rely on data from the southeast and mid-south regions of the Cotton Belt, which do not reflect the conditions in much of the southwestern region. Further, many producers in Oklahoma delay harvest-aid applications until the crop is nearly fully mature, potentially sacrificing fiber quality to weathering. The objective of this study was to determine the impact of applying harvest aids at various NACB levels in Oklahoma's short-season environment. A standard harvest aid mix was applied at 4-5 day intervals at two locations, Fort Cobb and Perkins, OK. Applications were made at 5.5, 4.0, 3.7, 3.2, and 2.7 NACB in Perkins and 7.0, 4.8, 4.0, 2.7, 1.7 in Fort Cobb. A non-treated control was also included at both locations. Prior to application boll diameter was measured to categorize bolls as either harvestable, or greater than or equal to the diameter of an American quarter ($\geq$ 24mm) which is commonly used as an example for harvestable boll size, or undersized (< 24 mm). It was concluded that the earlier applications resulted greater percentage of open harvestable bolls was achieved through applications as higher NACB values. The greater daily and total heat unit accumulation after application likely played a significant factor in the success of harvestable boll opening in the earlier application timings.

'Planting Green' Into Cereal Cover Crops Improves Horseweed (*Erigeron canadensis*) Suppression. John A. Schramski*, Christy Sprague, Karen A. Renner; Michigan State University, East Lansing, MI (008)

Herbicide-resistant horseweed (*Erigeron canadensis* L.) escapes throughout the growing season have Michigan soybean growers searching for alternative management strategies. Fall-planted cereal cover crops are a potential cultural control method for suppressing horseweed. However, Michigan's short cover crop planting window following cash crop harvest makes establishment and spring cover crop biomass accumulation for weed suppression challenging. Field experiments were conducted in three site-years to investigate the effects of fall-planted cereal cover crops terminated at different timings to manage herbicide-resistant horseweed. The experiment was a split-split-plot design with main plots of cereal rye and winter wheat drilled at 67 or 135 kg ha^{-1} and a no cover control established the fall prior. Within each main plot two termination timing subplots were established that included cover crop termination treatments of glyphosate applied one week prior to ('early termination') and one week after ('Planting Green') planting dicamba-resistant soybean. Dicamba was applied postemergence (POST) six weeks after planting to half of the plots, while the other half did not receive a POST herbicide application. Early terminated cereal rye averaged over seeding rate produced 1,546 kg ha^{-1} dry biomass. Biomass was two to three times greater compared with winter wheat in two out of three site-years. Delaying termination by 'Planting Green' increased cereal rye and winter wheat biomass production to 4,883 and 2,913 kg ha^{-1}, respectively. Cover crops did not consistently reduce horseweed density at any time during the season. However, early terminated cover crops reduced horseweed biomass at the time of termination by 60 to 71% compared with the no cover control. 'Planting Green' cover crops reduced horseweed biomass at the time of termination 59 to 98% in two out of three site-years. At the time of POST herbicide application, only high seeding rates of early terminated cover crops reduced horseweed biomass compared with the no cover control. In contrast, the additional cover residue remaining from 'Planting Green' covers reduced horseweed biomass by greater than 82% in all site-years. At horseweed maturity, neither early terminated nor 'Planting Green' cover crops consistently reduced horseweed biomass compared with the no cover control. However, inflorescent plant biomass at one site was 3X less in 'Planting Green' compared with early terminated plots when dicamba was not applied POST. Soybean yields were 30% greater in 'Planting Green' compared with early terminated covers at one site. At another site, soybean yields were 2X greater in 'Planting Green' with or without dicamba POST and in the early terminated plots with dicamba POST compared with early terminated plots that did not receive a POST herbicide application. Cover crops effectively reduced horseweed biomass compared with the no cover control at the time of termination, regardless of termination timing. However, delaying termination by 'Planting Green' increased cover crop biomass and provided greater horseweed suppression until the time of POST application. Utilizing fall-seeded cereal cover crops could improve early season horseweed control and aid an effective herbicide program.

Cover Crop Vs Cash Crop: A Comparison of Two Renovation Approaches in Deteriorated Wyoming Hayfields. Tyler Z. Jones*, Brian Mealor; University of Wyoming, Laramie, WY (009)

As alfalfa stands age, productivity declines, weeds encroach, and renovation becomes necessary - often through means of crop rotation, as autotoxins prohibit seeding back into established stands. Small grains are frequently used in rotation, but there is increasing interest in using cover crop mixes as rotational crops in these settings. However, little is known about renovating aged alfalfa stands in our region using cover crops. Our objectives were to determine if cover crops would boost soil health, provide quantifiable increases in alfalfa stand productivity, and suppress weeds, while providing a quality grazing resource equivalent to, or greater than, that obtained from cereal grain rotation crops. We implemented multi-year field study set in a split-plot randomized block complete design with two crop treatments (hay barley, cover crop mix) and two tillage treatments (conventional tillage, no-till), replicated in a dryland field and under pivot irrigation. In our dryland field tillage had the greatest effect on forage production regardless of crop type ($P<0.01$). When looking specifically at species seeded within each plot, biomass differed between crop types, but that difference was dependent on tillage type ($P<0.05$). Under irrigation, both tillage ($P<0.05$) and crop type ($P<0.001$) affected seeded species biomass. Thus far, our data indicate that our cover crop mix provided a similar quantity of forage as hay barley, however we are not yet able to determine the effect our mix will have on our longer-term questions of alfalfa productivity or soil health.

Control of Velvetleaf by Tank-Mixing Dicamba with Fluthiacet or Glyphosate in Dicamba/Glyphosate-Resistant Soybean. Jose H. de Sanctis*[1], Amit J. Jhala[1], Stevan Knezevic[2]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Concord, NE (010)

Velvetleaf is a major weed in corn and soybean production systems in the United States. Velvetleaf is an invasive weed that can produce up to 17000 hard-coated seeds that persist in soil for decades and germinate throughout the growing season when conditions are favorable. Moreover, this plant is highly competitive in corn and soybean crops and its natural tolerance to many herbicides makes velvetleaf difficult to control with the use of conventional weed control practices. The objective of this study was to evaluate the effects of velvetleaf height on post emergence herbicides efficacy in dicamba/glyphosate-resistant soybean. A field experiment was conducted in 2018 near Clay Center, Nebraska. The experiments were arranged in a split-plot design with four replications. The main plot treatments were the different velvetleaf heights (12 and 20 cm tall) and sub-plot treatments consisted on dicamba, glyphosate and/or fluthiacet-methyl different tank-mixtures applied at the maximum and minimum label rates plus an untreated control plot where velvetleaf was allowed to coexist with the soybean throughout the season. Treatments involving fluthiacet provided 91% or more of velvetleaf control for both application heights at maximum and minimum rates at 21 days after treatment (DAT). In dicamba applications when velvetleaf was 20 cm tall control varied from 86 to 31% for the maximum and minimum label dose applications, respectively. Moreover, dicamba applications when velvetleaf was 12 cm tall resulted in 93 and 66% of velvetleaf control for the aforementioned doses. Additionally, glyphosate also had a reduced efficacy when applied in velvetleaf plants with 20 cm, maximum and minimum label rates provided 93 and 20% of velvetleaf control, respectively.

Greenhouse Herbicide Screening for Industrial Hemp. Joseph Mettler*, Kirk A. Howatt; North Dakota State University, Fargo, ND (011)

In 2019, more than 59,000 hectares of hemp (*Cannabis sativa* L.) were grown in the United States. Industrial hemp has developed into a legitimate crop and is in need of chemical weed control options. There are no herbicides labeled for use in industrial hemp in the US. Canadian producers only have quizalofop and ethalfluralin labeled for use. The objective of these greenhouse experiments were to evaluate pre- and post-emergence herbicides for crop safety and identify which herbicides to further evaluate in the field. Herbicides that resulted in 25% injury or less were considered candidates for additional research. Both experiments were conducted in the greenhouse in 2019 in Fargo, North Dakota. Each experiment was established as a randomized complete block design (RCBD) with five replicates. Multiple modes of action were represented in separate pre- and post-emergence experiments. Experiments consisted of two runs and were combined for analysis using SAS 9.4 Proc Glimmix. Pre-emergence herbicides in mode of action groups 5, 15, and 27 resulted in greater than 40% injury. Hemp injury with pendimethalin or trifluralin as well as final biomass were similar to the non-treated. Pre-emergence herbicides selected for field experiments included imazethapyr, pendimethalin, trifluralin, quinclorac, saflufenacil, acetochlor, and pyroxasulfone. Post-emergence herbicides in groups 2, 8, 9, 14, and 27 were particularly injurious. Hemp injury and biomass yield with clopyralid was similar to the non-treated. Bromoxynil and dicamba also produced similar biomass to the non-treated. Post-emergence herbicides selected for field experiments included cloransulam, imazamox, clopyralid, quinclorac, bromoxynil, atrazine, and oxyfluorfen.

Timing of Post-Emergence Herbicide Application Impacts Weed Control and Seed Fecundity in Wisconsin Soybean Production. Sarah V. Striegel*, Maxwel Coura Oliveira, Ryan P. DeWerff, Nicholas J. Arneson, David E. Stoltenberg, Shawn P. Conley, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (012)

Preventing weeds from reaching maturity minimizes seedbank deposits and ultimately, reduces weed density and promotes greater efficacy of control measures in subsequent years. Effective post-emergence (POST) control of numerous problematic weed species has become more difficult to attain with increasing numbers of unique cases of herbicide resistance. While certainly a challenge in any cropping system, POST chemical control in soybean [*Glycine max* (L.) Merr] systems has become somewhat limited to the herbicide-tolerant trait option selected by the producer. A field study was conducted in Wisconsin at three sites in 2018 and four sites in 2019 to evaluate the impact of pre-emergence (PRE) fb dicamba + glyphosate applied post-emergence in dicamba-resistant (DR) soybeans at three timings: V1-V2, V3-V4, and V5-V6/R1 on overall weed control, crop yield, and weed seed fecundity. The addition of acetochlor post-emergence as part of the glyphosate + dicamba treatment was also evaluated. Weed species spectrum was site specific and included *Ambrosia trifida*, *Ambrosia artemiisifolia*, and *Amaranthus tuberculatus*. Application timing impacted weed control and crop yield at three out of seven site-years where the V3-V4 timing optimized both variables ($P < 0.05$), whereas acetochlor post-emergence did not influence these variables ($P > 0.05$). Weed seed fecundity of the predominant species at each location was reduced for all two pass programs in comparison with the nontreated control at all four site-years it was collected on; residual was not significant as a main effect across site-years ($P > 0.05$). Two site-years were able to detect differences between POST application times ($P < 0.05$), where the V3-V4 timing resulted in lower seed fecundity. The findings of this study will help producers using DR technology in determining the best time to complete a post-emergence application, consider the value of additional layered residual herbicide, and diversify their weed management programs.

Impact of Tank Mix partner on Solution pH and Secondary Movement of Dicamba and 2,4-D. Sarah V. Striegel*, Nikola Arsenijevic, Maxwel Coura Oliveira, Ryan P. DeWerff, David E. Stoltenberg, Shawn P. Conley, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (013)

Roundup Ready 2 Xtend® (glyphosate- and dicamba-resistant) and Enlist E3™ (glyphosate-, glufosinate- and 2,4-D-resistant) are two commercially available soybean [*Glycine max* (L.) Merr] trait options that provide growers with the opportunity to enhance post-emergence broadleaf weed control. Adoption of these technologies has also resulted in numerous cases of growth regulator injury in susceptible crops despite label restrictions in place to prevent cases of particle drift and secondary movement. Although many factors can impact potential for off-target movement (OTM), the focus of this research was to assess the role of glyphosate, a common addition in tank mixes with dicamba or 2,4-D, in influencing potential for secondary movement. The objective of this study was to investigate the impact components can have on spray solution pH and secondary movement. In 2019, lab experiments were completed testing the effect of two dicamba formulations, 2,4-D and glyphosate on solution pH. Additionally, a field experiment was conducted in Wisconsin to evaluate the secondary movement of select tank mixes using low-tunnel volatility trials. Briefly, low tunnel volatility trials consisted of off-site applications to flats filled with field soil placed between rows of susceptible soybeans under low tunnels. In lab experiments, the addition of glyphosate reduced spray solution pH when added to mixtures with dicamba or 2,4-D. In field experiments, greater symptomology was observed in dicamba treatments compared to 2,4-D treatments. Treatments with glyphosate did not result in greater symptomology ($P > 0.05$). Increased dicamba symptomology was observed for applications coinciding with high air temperature (maximum >29 C) and low wind speeds (mean < 1.5 m s^{-1}) for the 48 hour period following application. This research provides useful information regarding the impact of tank-mixtures and environmental conditions on secondary movement of dicamba and 2,4-D herbicides.

The Potential for New Residual Herbicides in Rice. Connor Webster*, Eric Webster, Benjamin M. McKnight, David C. Walker, Bradley Greer, Samer Y. Rustom; Louisiana State University, Baton Rouge, LA (014)

The Potential for New Residual Herbicides in RiceL.C. Webster, E.P. Webster, B.M. McKnight, D.C. Walker, W.B. Greer, S.Y. RustomIn order to combat herbicide resistance, growers are exploring non-labelled herbicides such as very-long-chain fatty acid inhibiting herbicides, also known as group 15 herbicides. A study was conducted in 2019 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana to evaluate the crop safety and potential weed control of group 15 herbicides in Louisiana rice production. Plot size was 3-m by 11.3-m with 16-19.5 cm drill-seeded rows of 'CL-111' at 78.4 kg ha^{-1}. The study was a randomized complete block with a two-factor factorial arrangement of treatments with three replications. Factor A consisted of acetochlor at 1,050 g ai ha^{-1}, dimethenamid at 940 g ai ha^{-1}, S-metolachlor at 1064 g ai ha^{-1}, pyroxasulfone at 119 g ai ha^{-1}, and pethoxamid at 661 g ai ha^{-1}. Factor B consisted of herbicides applied preemergence (PRE), delayed preemergence (DPRE) and early postemergence (EPOST). All DPRE and EPOST applications were applied with a crop oil concentrate at 1% v v^{-1}. All herbicide applications were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 93.5 L ha^{-1}. Visual evaluations for the study were recorded at 14 and 28 days after (DA) each timing for crop injury in addition to barnyardgrass and red rice control. Crop injury was observed at 55 and 32% when treated with acetochlor at 14 and 28 DA PRE, respectively. All other herbicides resulted in crop injury of 87 to 97% at 14 DA PRE and 75 to 95% at 28 DA PRE. Rice treated with all herbicides evaluated exceeded 41% and 36% injury at 14 and 28 DA DPRE, respectively. Crop injury of 20 and 21% was observed at 14 DA EPOST when treated with acetochlor or pethoxamid, respectively. At 28 DA EPOST, crop injury was 5 and 10% when treated with pethoxamid or acetochlor, respectively. Rice treated with all other herbicides resulted in 37 to 60% and 23 to 57% crop injury at 14 and 28 DA EPOST, respectively. These results indicate crop injury is reduced as the rice becomes more developed before application; however, a reduction in control of barnyardgrass and red rice was observed at the DPRE and EPOST timings compared with the herbicides applied PRE.

Effects of Deep Seeding on Weed Management and Crop Response in California Rice Systems. Alexander R. Ceseski*, Amar Godar, Kassim Al-Khatib; University of California, Davis, Davis, CA (015)

California rice (*Oryza sativa* L.) is grown as a monoculture, seeded by air into permanently-flooded basins. Decades of overreliance on a small number of herbicides have led to widespread herbicide resistance. The objectives of this study were to evaluate the weed management and crop physiology feasibilities of deep-drilled rice. Seeding deep should delay stand emergence and allow use of broad-spectrum herbicides on emerged weeds, without injuring the rice. This would make additional modes of action available for the mitigation of herbicide resistance. Seed of *cv.* M-206 and M-209 were dry-drilled to 3cm and 6cm, in a split-split-plot design with three herbicide programs and untreated control (UTC, treatment 1), over the 2018 and 2019 seasons. Herbicide programs centered on using glyphosate as a burndown treatment prior to stand emergence in all treated plots. Treatments were glyphosate (Roundup WeatherMax®) applied at 870g ae ha^{-1} just as rice was spiking, followed by (fb) bispyribac (Regiment CA®) at 45g ai ha^{-1} either alone (treatment 2) or tankmixed with pendimethalin (Prowl H2O®) at 430g ai ha^{-1} (treatment 3) or clomazone (Command 3ME®) at 225g ai ha^{-1} (treatment 4) applied at rice 3-leaf stage (3lsr), fb cyhalofop (Clincher CA®) at 125g ai ha^{-1} at 3.5lsr as a cleanup treatment for late-emerging *Leptochloa fusca* in all treated plots. Herbicides and required adjuvants were applied by CO_2-pressuized backpack sprayer with 8003VS flat-fan nozzles at 187 L ha^{-1}. Irrigation was by flushing every seven days until 28DAP, whereupon 10cm flood was established for the remainder of the season. Glyphosate alone was able to control > 60% of grasses and > 80% of sedges. Treated plots were weed-free by 60DAP and remained so for the remainder of the season. Stand emergence of up to 1cm for all plots was > 10% by 6 – 7 DAP, whereupon glyphosate was sprayed for all treated plots. Rice first-leaf tips died back after glyphosate application, but stands recovered and developed normally. Stands at 6cm planting decreased by 15.5% and 5.3% in 2018, but increased by 3.8% or were unchanged in 2019, for M-206 and M-209 respectively. Stand reductions were largely compensated for by increased tillering. Yields were not affected by 6cm depth for either *cv* in 2018, while in 2019 they increased by 5% or decreased by 3.4% for M-206 and M-209, respectively. Yields compared to nearby water-seeded fields were 2-22% and 3-11% higher in 2018 and 2019, respectively. We found that this program will allow the use of additional modes of action in California rice, and can achieve excellent weed control and competitive yield, given good field preparation and scouting, and accurate burndown application timing.

Evaluating Reduced Rate Post Herbicide Mixtures for Palmer Amaranth (*Amaranthus palmeri*) Control in Dry Bean. Clint W. Beiermann*[1], Cody F. Creech[1], Amit J. Jhala[2], Stevan Knezevic[3], Robert Harveson[1], Nevin Lawrence[1]; [1]University of Nebraska-Lincoln, Scottsbluff, NE, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]University of Nebraska-Lincoln, Concord, NE (016)

A reduced-rate split POST program was previously developed in dry bean to allow multiple applications for control of ALS-resistant pigweeds (*Amaranthus spp.*), however the program was not evaluated for Palmer amaranth (*Amaranthus palmeri*) control. A study was initiated in 2017 and 2019 near Scottsbluff, NE to evaluate the performance of a split-POST application herbicide program for control of Palmer amaranth. The study was arranged as a two-factor strip-plot design. Strip-plot factor consisted of no-PRE, or pendimethalin (1070 g ai ha^{-1}) + dimethenamid-P (790 g ai ha^{-1}) applied PRE. Main plot factor, POST herbicide treatment, consisted of all labeled combinations of imazamox, bentazon, and fomesafen applied in one and two pass programs at standard rates, and reduced rate treatments consisting of imazamox (9 g ai ha^{-1}) + bentazon (314 g ai ha^{-1}) + fomesafen (70 g ai ha^{-1}) applied in one, two, and three sequential applications. In both years, the use of a PRE herbicide reduced Palmer amaranth density and biomass. In 2017 all POST treatments reduced Palmer amaranth density compared to non-treated plots. In 2019 all POST treatments reduced Palmer amaranth density compared to non-treated and imazamox + bentazon fb bentazon when no PRE was applied. In 2017, all POST treatments reduced Palmer amaranth biomass compared to non-treated treatments, when a PRE was applied. In 2019, all POST treatments reduced Palmer amaranth biomass compared to the non-treated treatments. The two and three pass microrate system did not enhance weed control compared to a one-pass treatment containing fomesafen at labeled rates.

Effect of Sublethal 2,4-D Rates on Quality and Value of Cotton Fiber. Bradley R. Wilson*[1], Misha R. Manuchehri[1], Peter A. Dotray[2], Wayne Keeling[3], Gaylon Morgan[4], Seth A. Byrd[1]; [1]Oklahoma State University, Stillwater, OK, [2]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX, [3]Texas A&M AgriLife Research, Lubbock, TX, [4]Cotton Incorporated, Cary, NC (017)

Injury due to 2,4-D has been well documented across the Cotton Belt, although impacts on cotton fiber quality are largely unknown. To determine the effects of sublethal rates of 2,4-D on non-tolerant cotton, a study was conducted in 2013, 2014, and 2015 in Lubbock, TX. Five sublethal rates of 2,4-D were applied at the nine leaf and first bloom growth stages, with a non-treated control (NTC) included at both stages. The five rates represented fractions of the full rate of 2,4-D choline plus glyphosate at 2.22 kg ae ha^{-1}: 0.0008, 0.008, 0.08, 0.8, and 8%. After harvest and ginning, fiber quality was determined through USDA classing procedures. Compared to the NTC, micronaire and uniformity were reduced at the 8% rate in 2013 and at the 0.8 and 8% rates in 2015. In all years of the study fiber strength was reduced at the 8% rate compared to the NTC. Cotton loan value and gross return per hectare decreased following the 0.8 and 8% rates in 2013 and 2015. Due to unfavorable growing conditions during the 2014 season, fiber quality and loan value were not affected by 2,4-D. However, cotton yield loss due to 2,4-D resulted in a reduced gross return at the 0.08, 0.8, and 8% rates. This study suggests that sublethal rates of 2,4-D on non-tolerant cotton does cause a reduction in cotton fiber quality, adversely affecting gross profits through declines in both yield and value of lint in years where conditions are favorable to produce high quality fiber.

Options for Managing Weedy Rice in Louisiana. Bradley Greer*[1], Eric Webster[1], Benjamin M. McKnight[1], David C. Walker[1], Samer Y. Rustom[1], Connor Webster[1], Justin B. Hensley[2]; [1]Louisiana State University, Baton Rouge, LA, [2]Arkansas Ag Specialists, LLC, Dumas, AR (018)

Developing new and improved strategies for weedy rice (*Oryza sativa* L.) control is essential for Louisiana rice (*O. sativa* L.) growers. The use of herbicide-resistant rice such as imidazolinone- or ACCase-resistant varieties provide growers with the added benefit of controlling weedy rice throughout the growing season. However, poor stewardship has led to numerous documented cases of imazethapyr-resistant weedy rice populations. A new option for weedy rice control is ACCase-resistant varieties which have no documented cases of weedy rice resistance to date. If good stewardship of this technology is not followed, resistance will occur. Weedy rice samples were collected from rice fields throughout the state of Louisiana and southern Arkansas during the 2019 rice harvest. In total, 67 accessions were collected from 9 different parishes in Louisiana and 1 county in Arkansas. The major parameters for collection were hull color and the presence or absence of awns. If a field had multiple phenotypes those were collected as separate samples. A greenhouse study was conducted in 2020 on the campus of Louisiana State University in Baton Rouge, LA to evaluate the tolerance of weedy rice samples to quizalofop and imazethapyr. Weedy rice was planted in plastic containers with a diameter of 7 cm, a depth of 25 cm, and a volume of

660 ml. Containers were filled with potting soil and three pre-germinated seedlings from each sample were planted per container. Rice was planted on January 8, 2020 and thinned to one plant per container a week later. A randomized complete block design with 5 replications was utilized and the treatments were nontreated, quizalofop at 120 g ai ha^{-1}, or imazethapyr at 105 g ai ha^{-1}. Applications were made at the two- to three-leaf stage on January 23, 2020. Plant heights were collected at 0, 1, 3, 7, 14, and 21 days after application. Heights were taken during these early periods after applications to evaluate how quickly the herbicides stop plant growth. Quizalofop stopped growth of the weedy rice almost immediately after application, with very little growth observed. Increased heights were observed in weedy rice treated with imazethapyr over the 21-day period. Increased tillering was also observed in the weedy rice treated with imazethapyr which has been observed in previous research. At 14 days after application, visual injury was observed on the weedy rice treated with quizalofop. However, little to no injury was observed with the weedy rice treated with imazethapyr. Greater than 95% control was observed on all weedy rice accessions treated with quizalofop at 21 days after application. Of the 67 accessions evaluated at 21 days after application, only 9 were controlled 50% or better when weedy rice was treated with imazethapyr. With 87% of the accessions in this study showing little to no control of weedy rice when imazethapyr is applied, it is likely that a majority of the weedy rice in Louisiana is resistant to imazethapyr. It is important to protect the ACCase-resistant varieties from weedy rice resistance issues by rotating between imidazilinone-resistant rice varieties, and glufosinate-resistant soybeans (*Glycine max* (L.) Merr.).

Carry Over Effects of Residual Cotton Herbicides on Fall-Planted Cover Crops. Enelise Osco Helvig*[1], Spencer L. Samuelson[2], Cleber D. de Goes Maciel[1], Muthukumar V. Bagavathiannan[2]; [1]Universidade Estadual do Centro Oeste, Guarapuava, Brazil, [2]Texas A&M University, College Station, TX (019)

Cover crops have been adopted by growers in different cropping systems due to potential benefits with weed management and improving soil quality. Cover crops are typically established in the fall season, following the harvest of the summer crop; some herbicides applied in the summer crop can persist in the soil for prolonged periods and affect the establishment and growth of the cover crops. A field study was conducted in 2019/2020 at the Texas A&M University Research Farm, College Station, Texas, to observe the effect of eleven soil applied residual herbicides commonly used in cotton, on the injury level and biomass production of ten winter cover crop species (crimson clover, shield mustard, mustard, oilseed radish, turnip, cereal rye, oat, wheat and triticale). The herbicides diuron, prometryn, fluometuron, *S*-metolachlor and pendimethalin were applied PRE, at 156 days prior to cover crop planting. Fomesafen, diuron, acetochlor and *S*-metolachlor were applied 113 days prior to cover crop planting, whereas flumioxazin and diuron at 83 days prior to cover crop planting, all as POST to the cotton crop. Cover crops were planted on 10/24/2019; crop injury and biomass were evaluated at 28 days after cover crop emergence. For PRE applications, shield mustard was the most sensitive species, wherein prometryn, diuron, *S*-metolachlor and fluometuron caused 92, 87, 83 and 47% injury, respectively. For POST applications, fomesafen caused the most injury on a greater number of cover crop species, with severe crop damage observed on shield mustard (100% injury), oilseed radish (100%), turnip (100%), mustard (99%) and wheat (95%). For flumioxazin and diuron, the most injuries were recorded on crimson clover (55%) and shield mustard (45%), respectively. With respect to biomass, fomesafen caused severe biomass reduction (100% reduction) in shield mustard, oilseed radish, and turnip. Likewise, acetochlor caused substantial biomass reduction in crimson clover (51%), oat (37%), and shield mustard (36%). Overall, crimson clover and shield mustard were significantly affected by a wide range of cotton herbicides. Findings provide novel insights on the sensitivity of important cover crop species planted following cotton treated with in-season residual herbicides, and will facilitate the selection of suitable cover crop species.

Evaluation of New Rice Herbicides Applied in a Salvage Situation. Samer Y. Rustom*, Eric Webster, Benjamin M. McKnight, Connor Webster, Bradley Greer, David C. Walker; Louisiana State University, Baton Rouge, LA (020)

Weed management in rice typically occurs early in the growing season; however, this approach sometimes fails prior to permanent flood establishment. Postemergence weed management after the flood is established is often referred to as a salvage situation. Salvage treatments can be problematic due to the advanced growth stage of weeds and inadequate herbicide coverage. Research was conducted at the LSU AgCenter H. Rouse Caffey Rice Research Station near Crowley, LA to evaluate the potential of new rice herbicides applied in a salvage situation. Herbicides evaluated were: florpyrauxifen-benzyl at 14.5 and 29 g ai ha^{-1}, halosulfuron at 53 g ai ha^{-1}, halosulfuron plus prosulfuron at 55 and 83 g ai ha^{-1}, halosulfuron plus thifensulfuron at 53 g ai ha^{-1}, orthosulfamuron at 94 g ai ha^{-1}, and orthosulfamuron plus quinclorac at 490 g ai ha^{-1}. Treatments were applied after flooding when rice was at the 2- to 3-tiller growth stage with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} with five flat-fan 110015 nozzles spaced 35 cm apart. At 28 DAT, each rate of florpyrauxifen-benzyl, the 83 g ha^{-1} rate of halosulfuron plus prosulfuron, and orthosulfamuron plus quinclorac controlled *Alternanthera philoxeroides* (Mart.) Griseb. (alligatorweed) greater than 89%. Control for alligatorweed was reduced when treated with all other herbicides and rates evaluated. At 42 DAT, All halosulfuron-containing products and the 29 g ha^{-1} rate of florpyrauxifen-benzyl controlled *Cyperus esculentus* L. (Yellow nutsedge) 92 to 99%. Control was reduced for all other products and rates evaluated. Rice treated with halosulfuron plus prosulfuron at 83 g ha^{-1} resulted in a rough rice yield of 4560 kg ha^{-1}. Yield was reduced to 3670 kg ha^{-1} when treated with the 29 g ha^{-1} rate of florpyrauxifen-benzyl.

Characterization of Dicamba Cross Resistance in a Multiple-Resistant Waterhemp (*Amaranthus tuberculatus*) Population from Illinois. Lucas Bobadilla*, Darci A. Giacomini, Patrick Tranel; University of Illinois, Urbana, IL (021)

Waterhemp (*Amaranthus tuberculatus*), for the last decades, has been one of the most common and troublesome weeds of corn and soybean in the USA. A specific waterhemp population from Illinois, USA (named CHR) was found to have resistance to herbicides spanning five different modes of action. Despite no history of dicamba applications to this field, some plants in this population survived field rates of dicamba application, indicating a potential presence of a natural occurrence of cross-resistance. The objective of this study was to characterize the level and the inheritance of dicamba resistance, and to evaluate if metabolism inhibitors could overcome dicamba resistance in CHR plants. F_1, back-crosses, and pseudo-F_2 populations were developed using as parents CHR and a sensitive standard population designated as WUS. Results from inheritance studies indicated that dicamba resistance is an incompletely dominant and multi-genic trait. A resistance index level of 10 was identified based on biomass and plant area reduction. The application of metabolism inhibitors showed that malathion increased the damage caused by dicamba application, indicating potential involvement of a cytochrome P-450 as a key player in the resistance mechanism; however, other minor genes may be involved. Inhibition of glutathione-S-transferase did not show any effect in reducing the resistance level of CHR. Further studies using RNA-seq are underway to identify potential genes involved in the resistance mechanism.

Effects of Simulated Dew on Dicamba Volatility and Soybean Sensitivity. Matthew Osterholt*[1], Julie M. Young[2], Bryan G. Young[2]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, Brookston, IN (022)

A concern with in-crop applications of dicamba to dicamba-resistant soybean (Glycine max (L.) Merr.) is the potential for off-target movement to sensitive crops. Little research is available on whether dew influences dicamba volatility from treated soybean leaf surfaces. In addition, no research is available on whether the presence of dew influences dicamba-sensitive soybean response to dicamba vapor. As a result, a low tunnel experiment was conducted in 2019 to evaluate the influence of simulated dew on 1) dicamba volatility from dicamba-treated soybean leaf surfaces and 2) the response of sensitive soybean to dicamba vapor. The experiment was conducted utilizing a two-factor factorial in a randomized complete block design with four replications. Factor A was the presence or absence of dew applied to dicamba-resistant soybean grown in greenhouse flats. Factor B was the presence or absence of dew applied to the rows of planted dicamba-sensitive soybean under the low tunnel. Dicamba was applied at 2240 g ae ha^{-1} to the flats of dicamba-resistant soybean at a remote location and introduced to the low tunnels thereafter. The dicamba-treated soybean flats were placed in the middle of a 6m long plot that consisted of two rows of dicamba-sensitive soybean. A plastic sheet was drawn over a tunnel structure covering the entirety of the plot. Dew events were simulated for three consecutive nights at a rate equivalent to 245 L ha^{-1}, based on the amount of dew collected from soybean at the site prior to initiating the experiment. In order to apply dew to the dicamba treated flats, the flats were extracted from the tunnel, administered a dew event utilizing a single-nozzle misting system, and replaced to their original position in the tunnel. To apply a simulated dew to the sensitive-soybean, the dicamba treated flats were extracted, dew applied to the sensitive soybean utilizing a seven-nozzle misting system hung inside the tunnel structure, and dicamba treated soybean were reinserted back into the tent. When dew was present on the dicamba-treated soybean flats, injury to the sensitive soybean at the center of the tunnel increased from 20 to 28% and height was reduced from 47 to 42 cm. When dew was present on the sensitive soybean rows, soybean injury increased from 18 to 30% and height was reduced from 48 to 40 cm. At the end of the tunnel, approximately 300 cm from the dicamba treated flats, soybean injury increased from 6 to 9% and height was reduced from 55 to 49 cm when dew was present on the dicamba-treated soybean. In addition, soybean injury was increased from 5 to 10% and height was reduced from 56 to 49 cm when dew was present on the dicamba-sensitive soybean rows. These results indicate that dew increases the volatility potential of dicamba from soybean leaves, as well as an increasing the response of sensitive soybean in the presence of dicamba vapor. This research will be repeated in 2020 and validated in controlled environment chambers.

Assessment of North Carolina Farmer's Glufosinate Use and Applications. Eric A. Jones*, Wesley Everman, Ramon G. Leon, Charlie W. Cahoon; North Carolina State University, Raleigh, NC (023)

Glufosinate resistance has yet to evolve in any broadleaf weed globally. However since many broadleaf weeds, such as *Amaranthus palmeri* (Palmer amaranth) exhibit multiple herbicide resistance, glufosinate may be applied more extensively to control herbicide-resistant weeds. If this is indeed the fate for weed control, the evolution of glufosinate resistance is inevitable. Determination of farmer's glufosinate use was assessed by handing out a survey at the row crop extension meetings in the winter of 2019. The results of the survey indicated that 85% of respondents were concerned about glufosinate-resistant weeds becoming a problem on their farm. North Carolina farmers are using glufosinate for resistance management (48%), a complementary herbicide (22%), or a main herbicide for weed control (17%). The surveyed farmers also responded that glufosinate was primarily applied at EPOST (25%), while applications of burndown, POST, Layby, and combinations were represented as well. The question "have you realized a control failure with glufosinate?" resulted in 30% of the respondents replying "yes" and 70% replying "no". The results of this survey provide evidence that North Carolina farmers are concerned about glufosinate resistance and are trying to prolong the efficacy of glufosinate.

Using Reduced Rates of Quizalofip to Control Weedy Rice. David C. Walker*[1], Eric Webster[1], Ronald J. Levy Jr.[2], Benjamin M. McKnight[1], Samer Y. Rustom[1], Lucas C. Webster[1], William B. Greer[1]; [1]Louisiana State University, Baton Rouge, LA, [2]Louisiana State University, Rayne, LA (024)

A current weed management issue in rice-producing areas throughout the world is the management of weedy rice (*Oryza sativa* L.), more particularly, imidazolinone-resistant (IR) weedy rice. With concerns around IR weedy rice resistance, BASF developed a new herbicide resistant-rice sold under the trade name Provisia®. The herbicide targeted for use is quizalofop, which will also be sold under the trade name Provisia®. Quizalofop is a Group 1 herbicide, which inhibits the acetyl-coA carboxylase (ACCase) enzyme. The targeted single quizalofop application rate in ACCase-resistant rice production is 92 to 155 g ha^{-1}, not to exceed 240 g ha^{-1} yr^{-1}. Research was conducted at the Rice Research Station near Crowley, Louisiana to evaluate the activity of quizalofop at different rates for management of weedy rice. Quizalofop was applied at 23.2, 46.2, 69.2, 92.4, and 116 g ha^{-1} to weedy rice at the two- to three-leaf stage and at panicle initiation to determine the rate needed for control. Quizalofop was applied with a crop oil concentrate at 1% v v^{-1}. All herbicide applications were applied with a CO_2 pressurized backpack sprayer calibrated to deliver 93.5 L ha^{-1}. Plot size was 3 m by 11.3 m with 16, 19.5 cm drill-seeded rows of weedy rice planted at 67 kg ha^{-1}. The study was a randomized complete block with three replications. In order to have an accurate representation of a weedy rice population, four separate studies were conducted using four different types of weedy rice: a conventional line, an imidazolinone-resistant hybrid line, an inbred imidazolinone-resistant hybrid line, and red rice. Weedy rice control was recorded at 7, 14 and 28 days after treatment (DAT) and plant heights were recorded at 7 and 28 DAT and at crop maturity. Results indicated that 93 g ai ha^{-1} of florpyrauxifen adequately controlled Cl-111, ClXL-745 and red rice while 46 g ai ha^{-1} adequately controlled Mermantau weedy rice at least 28 DAT. Therefore, reduced rates can be used to manage weedy rice and minimize the amount of applied active ingredient throughout the growing season.

Cover Crops as a Summer Annual Weed Management Tool in Dryland Corn Cropping Systems of Semi-Arid Nebraska. Alexandre T. Rosa*[1], Cody F. Creech[2], Roger Elmore[1], Daran Rudnick[1], John Lindquist[1], Rodrigo Werle[3]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Scottsbluff, NE, [3]University of Wisconsin-Madison, Madison, WI (025)

Producers are questioning whether the incorporation of cover crops (CC) in semi-arid areas would aid to weed suppression and impact grain yield of subsequent crops. The objective of this study was to summarize the effects of CC on summer annual weed management and corn grain yield. Data was collected from three experiments conducted in western Nebraska from 2017 to 2019. Cover crop treatments were classified as i) winter-sensitive mixture killed in the winter, ii) winter-hardy mixture terminated with glyphosate in the spring and iii) no CC. Cover crops were planted in the fall, following winter-wheat harvest. Cover crop biomass was collected in the fall and spring. Corn was planted mid to late-May. Weed density and biomass, and crop residue in the soil surface were collected when corn reached the V6 growth stage. The predominant weed species found in western NE were prostrate pigweed (*Amaranthus blitoides*) and witchgrass (*Panicum capillare*). A canonical discriminant analysis (CDA) and Spearman's rank correlation test allowed us to visualize the potential of summer annual weeds reduction by cover crop adoption. The CDA showed that CC fall biomass was related to winter-sensitive mixture; the CC spring biomass and crop residue in the soil surface were strongly related to winter-hardy mixture; and, the no CC treatment clustered towards the variables weed biomass and corn grain yield. Correlations of CC fall biomass with weed measurements were not significant. On the other hand, weed density and biomass were negatively correlated with CC spring biomass ($R = -0.15$ and $R = -0.18$, respectively) and crop residue in the soil surface ($R = -0.22$ and $R = -0.20$, respectively). However, the winter-sensitive and winter-hardy CC mixtures reduced corn grain yield in 12 and 17.7% compared to no CC treatment, respectively. Thus, our findings suggest that the adoption of CC has the potential to suppress weeds. Further, it is imperative to maximize growth when using CC to aid weed management. However, the risks of negative effects of excessive CC growth on the yield of the subsequent crop should be considered in rainfed areas of semi-arid regions.

Cover Crops and Wheat Stubble Management Effects on Weed Demographics and Corn Productivity in Semi-Arid Nebraska. Alexandre T. Rosa*[1], Cody F. Creech[2], Roger Elmore[1], Daran Rudnick[1], John Lindquist[1], Chuck Burr[3], Strahinja Stepanovic[4], Rodrigo Werle[5]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Scottsbluff, NE, [3]University of Nebraska-Lincoln, North Platte, NE, [4]University of Nebraska-Lincoln, Grant, NE, [5]University of Wisconsin-Madison, Madison, WI (026)

Producers are questioning whether the incorporation of cover crops (CC) in semi-arid areas would aid weed management and impact grain yield of subsequent crops. The objective of this study was to evaluate the impact of wheat stubble management height combined with CC species selection

on soil water and nitrogen levels, weed demographics, and subsequent corn productivity. The study was established in 2017 and 2018 at four locations in western NE. Treatments consisted of two wheat stubble heights (short and tall) and three CC mixes: i) winter-sensitive mixture (WS) killed in the winter, ii) winter-hardy mixture (WH) terminated 2 weeks before corn planting with glyphosate, and iii) no CC (NCC). The experiment was conducted in a randomized complete block design with split-plot with four replications, where wheat stubble height was the whole-plot, and CC mixes the split-plot. Cover crop biomass was collected during the fall and spring. Corn was planted mid to late-May. Soil water readings were recorded during CC and corn growing seasons. Weed density and biomass, and soil samples were collected when corn reached the V6 growth stage. Single-Proton Avalanche Diode (SPAD) readings were taken when corn reached the R2 growth stage. Lower soil water content was detected in WS and WH treatments late in fall 2017. By the end of spring 2018, WH reduced soil water content by 9 and 13 % when compared to WS and NCC treatments. Tall wheat stubble reduced weed density by 37% compared to short stubble across locations. Winter-hardy species reduced weed density by 50% compared to NCC treatment at Sidney 2017. No significant differences between treatments were found in weed biomass at any location. The SPAD readings were lower under WS and WH treatments as compared to NCC. The WH species reduced corn grain yield by 1140 and 770 kg ha^{-1} compared to NCC and WS treatments. Cover crops and wheat stubble management have the potential to suppress summer annual weeds. However, CC reduced soil water content, and likely induced nitrogen immobilization, reducing corn grain yield. Caution and proper management should be taken when incorporating CC in cropping systems of semi-arid regions.

Benzobicyclon Utility for Weed Rice Control. Mason C. Castner*, Jason K. Norsworthy, Chad Brabham, Fidel Gonzalez Torralva; University of Arkansas, Fayetteville, AR (027)

Weedy rice (*Oryza sativa*) is one of the most problematic weeds to Midsouth rice production due to a lack of chemical control options as well as its adverse influence on grain quality. Not only are chemical control options limited, the effective window for controlling weedy rice is likely a function of size. In order to evaluate the scope of herbicidal activity of benzobicyclon, experiments were conducted near Stuttgart, Arkansas, and Colt, Arkansas in 2019. A total of 15 weedy rice accessions and 5 known rice cultivars were planted at two separate timings and flooded when the initial planting reached the 4- to 5-leaf stage at Colt and had 1 to 2 tillers at Stuttgart to determine the efficacy of benzobicyclon at differing growth stages. Treatments were arranged as a two-factor split-plot with three replications, with the whole-plot factor being size at application (3 to 4 leaf or 1 to 2 tillers at Stuttgart; 1 to 2 leaf or 4 to 5 leaf at Colt) and sub-plot factor being accession. An interaction of accession and application timing was observed for injury at both 14 and 28 days after treatment (DAT). Overall, smaller, later planted accessions saw greater injury in comparison to earlier planted accessions. However, highly sensitive accessions or rice cultivars were effectively controlled or severely injured at both application timings. Injury from a cross between Purple Marker, a sensitive cultivar, and RoyJ, a tolerant cultivar, showed partial tolerance when applications exceeded the 3- to 4- leaf stage. The tolerant commercial cultivar LaKast exhibited minimal injury, regardless of application timing. Ultimately, benzobicyclon is most effective when applied to weedy rice prior to the 3-leaf growth stage or when weedy rice plants do not express a functional HIS1 gene.

Control of Johnsongrass (*Sorghum halepense*) and Foxtails with Post-Emergence Herbicides in Yellow and White Popcorn Hyprids. Samantha D. Isaacson*, Amit J. Jhala, John Lindquist; University of Nebraska-Lincoln, Lincoln, NE (028)

As there are a limited number of herbicides labeled in popcorn and even fewer with activity in grassy weeds, grassy weed control is one of the biggest challenges that popcorn producers face. It is perceived that white popcorn is more sensitive to herbicides than yellow popcorn which further limits available herbicides for white hybrids. Johnsongrass (*Sorghum halepense)* and foxtail species are some of the hardest to control grasses for Nebraskan popcorn producers. The objective of this study was to compare the grassy weed control of six post emergence herbicides and observe if they cause any herbicide injury in white or yellow popcorn. Field experiments were conducted near Clay Center, Nebraska in 2019. The field chosen had a large, even seedbank of yellow foxtail *(Setaria pumila),* green foxtail *(Setaria viridis),* and giant foxtail *(Setaria faberi).* Johnsongrass was broadcasted into the field. Two popcorn hybrids were tested, one white and one yellow. Six different herbicides were tested with two controls, a weed-free control and non-treated control. The experiment used a strip plot design for the popcorn hybrids and a randomized complete block design for the herbicide treatments. Weed biomass and weed density of all grassy weed species were recorded eight and eleven weeks after planting. No herbicide injury was observed in either popcorn hybrid. Tembotrione was the only post emergent herbicide that provided an acceptable level of control. The other five group 2 and group 27 herbicides had low, unacceptable levels of grass control. The yields in the weed-free control, tembotrione, and the nicosulfuron/mesotrione mix were not significantly different. It is clear that popcorn producers cannot rely solely on a post emergent herbicide for grass control. Popcorn producers must use an integrated weed management approach in order to achieve acceptable levels of weed control.

Weed Management and Crop Response Utilizing Isoxaflutole in HPPD Tolerant Cotton. Delaney C. Foster*[1], Peter A. Dotray[2], Corey Thompson[3], Greg Baldwin[4], Frederick Moore[5]; [1]Texas Tech University, Lubbock, TX, [2]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX, [3]BASF, Abernathy, TX, [4]BASF, Research Triangle Park, NC, [5]BASF, Lubbock, TX (029)

Over half of the nation's cotton is planted in Texas with 1.6 million hectare residing in the High Plains region. Since 2011, glyphosate resistant Palmer amaranth has threatened Texas cotton production and alternatives to glyphosate-based systems are needed. Integrating soil residual herbicides such as isoxaflutole into a weed management system is an effective strategy to control glyphosate resistant weeds before they emerge. BASF Corporation is developing hydroxyphenylpyruvate dioxygenase (HPPD) tolerant cotton, which will allow growers to utilize isoxaflutole, an HPPD inhibiting HRAC Group F2 herbicide, in future weed management programs. In 2019, field experiments were conducted in New Deal, Lubbock, and Halfway, Texas to determine HPPD-tolerant cotton response to isoxaflutole applied preemergence (PRE) or early-postemergence (EPOST) to 2- to 4-leaf cotton as well as to determine the efficacy of isoxaflutole when used as part of a weed management program. Cotton response experiments at New Deal and Lubbock included: prometryn PRE at 1.35 kg ai/ha followed by (fb) glufosinate at 0.88 kg ai/ha + *S*-metolachlor at 1.4 kg ai/ha EPOST, isoxaflutole at 0.11 kg ai/ha + prometryn PRE fb dimethenamid at 0.84 kg ai/ha + glufosinate EPOST, isoxaflutole + pendimethalin at 1.12 kg ai/ha

PRE fb dimethenamid + glufosinate EPOST, isoxaflutole + prometryn + pendimethalin PRE fb dimethenamid + glufosinate EPOST, isoxaflutole + prometryn at 0.67 kg ai/ha (½ rate) PRE fb glufosinate + *S*-metolachlor EPOST, isoxaflutole + prometryn PRE fb glufosinate + *S*-metolachlor EPOST, isoxaflutole + fluometuron at 1.12 kg ai/ha PRE fb glufosinate + *S*-metolachlor EPOST, prometryn PRE fb isoxaflutole + glufosinate EPOST, and prometryn PRE fb isoxaflutole + glufosinate + glyphosate at 2.1 kg ai/ha EPOST. A blanket mid-postemergence (MPOST) glyphosate + glufosinate application was made at first bloom and some treatments received diuron postemergence-directed (PDIR) when cotton was at the bloom stage. At New Deal, no cotton response was observed following any PRE treatment. Following the EPOST application, injury did not exceed 13% 14 days after application (DAA) and did not exceed 5% 28 DAA. No cotton response was observed after the MPOST and PDIR applications. Cotton lint yield ranged from 1030 to 1217 kg/ha and no treatment adversely affected yield when compared with the nontreated weed-free control. At the Lubbock location, cotton response was greatest early season but never exceeded 14%, with the treatment exhibiting the highest response being isoxaflutole+prometryn applied PRE. One week after the EPOST application, all treatments exhibited 10 to 15% injury, which declined to less than 10% 14 DAA. Cotton lint yield following all herbicide treatments ranged from 675 to 757 kg/ha and were similar to the nontreated weed-free control. In a non-crop weed control study at Halfway, treatments mimicked the cotton response trials with the addition of two treatments: isoxaflutole + prometryn PRE fb glyphosate + dicamba at 0.56 kg ai/ha EPOST and prometryn PRE fb isoxaflutole + glyphosate + dicamba EPOST. These two treatments included glyphosate + dicamba MPOST. Fourteen days after the PRE application, all treatments controlled Palmer amaranth >94% except for isoxaflutole + pendimethalin PRE (88%). Twenty-one days after the EPOST application, all treatments controlled Palmer amaranth >90%. When evaluated 21 days after the PDIR application, treatments that did not receive diuron were less effective (up to 20%) at controlling Palmer amaranth. The opportunity to use isoxaflutole in cotton will improve season-long control of Palmer amaranth when used as part of an overall weed management program.

Effect of Winter Wheat Cover Crop Termination Time on Dry Bean Productions. Tyler C. Hicks*[1], Andrew R. Kniss[2], David A. Claypool[2]; [1]University of Wyoming, Fort Collins, CO, [2]University of Wyoming, Laramie, WY (030)

Direct harvest of dry edible beans is becoming more common in Wyoming and Nebraska. Cover crops for weed control or soil health are also increasing, and past research has shown that the presence of a cover crop influences dry bean node and pod heights. A field study was conducted in the summer of 2019 in Lingle, Wyoming to evaluate how cover crop removal timing influenced pod height and direct harvest loss in three dry bean cultivars. The experimental design was a split-plot arrangement of winter wheat termination timing (whole plot) and bean cultivar (split-plot) set within a randomized complete block design with 8 replicates. Dry edible bean cultivars were chosen based on their height: 'Lariat' (tall variety), 'Othello' (low variety), and 'Staybright' (intermediate variety). Beans were planted directly into a winter wheat cover crop that was terminated at timings from 14 days before planting to 28 days after planting. If the cover crop was terminated more than 2 days after bean planting the first trifoliolate node height increased for all cultivars. Lowest pod height was affected by wheat termination times of 4 to 8 days after bean planting for Othello and Staybright varieties. Bean yield was reduced if the cover crop was terminated more than 10 days after planting for the Othello and Staybright varieties. These results suggest a window between 2 and 10 days after bean planting for cover termination to improve harvest efficiency without reducing yield.

Sphere of Influence of Palmer Amaranth (*Amaranthus palmeri*) in Cotton (*Gossypium hirsutum*). Nicholas T. Basinger*[1], David Weisberger[1], Logan M. Dyer[1], Ramon G. Leon[2]; [1]University of Georgia, Athens, GA, [2]North Carolina State University, Raleigh, NC (031)

Palmer amaranth (*Amaranthus palmeri* S. Watson) can significantly reduce yields in Southeastern cotton (*Gossypium hirsutum*) production scenarios. *A. palmeri* has the potential to be very competitive with cotton due to its quick establishment time, short reproductive cycle, and high degree of seed production. In general, weed population distributions within a field can vary, as can patterns of crop-weed interference. One method of understanding interference is through an evaluation of the sphere of influence, the spatial extent of a given weeds' competitive ability. To explore the sphere of influence of *A. palmeri*, studies were established at two University of Georgia research farms, Iron Horse and the J. Phil Campbell, both located in Watkinsville, GA. Two densities (1 and 10 plants m^2), and a control (0 plants m^2), of *A. palmeri* were established adjacent to a given cotton row. Cotton height, number of nodes, whole plant biomass, bolls per plant, and seed lint yield were measured at 4 distances (0, 1, 2, 3 m) from the established *A. palmeri* plants. The sphere of influence was not found at 1 plant per m^2. At J. Phil Campbell, the sphere of influence for cotton height was 0.28 m. At 10 plants per m^2 the sphere of influence for boll number and seed lint yield was 0.72 m and 0.71 m, respectively. At Iron Horse there was no observable sphere of influence for any *A. palmeri* density. Results suggest that *A. palmeri* will influence cotton yield through the reduction of plant height, cotton boll number, and seed lint yield, but that the sphere of influence may be variable across densities, sites and response variables.

Using Pesticides Wisely – Georgia 2019. A Stanley Culpepper*[1], Jenna C. Vance[1], Thomas Gray[2], Laura P. Johnson[3], Eric P. Prostko[1]; [1]University of Georgia, Tifton, GA, [2]Georgia Department of Agriculture, Atlanta, GA, [3]University of Georgia, Athens, GA (032)

As the world's population is expected to approach 10 billion people by 2050, family farms are challenged with the task of providing feed, food, and fiber for all. To meet this demand, science confirms that growers must have access to economically effective pesticides. However, it is equally important that all pesticides are used carefully and strategically in ways that protect the consumer, the grower and their neighbors, and our environment. Therefore, the University of Georgia (UGA) and Georgia Department of Agriculture (GDA) developed an educational training program titled "Using Pesticides Wisely" (UPW). This program shares innovative research results from over 112 experiments designed to help pesticide applicators improve on-target pesticide applications. From 2015 through 2019, the UPW classroom training has been conducted at 76 locations with 6,806 people in attendance; the training was conducted at 31 locations with 3,121 individuals attending during 2019. Additionally, UGA Extension Agents conducted a one-on-one training program to supplement the classroom trainings, using on-farm visits to further share practical scientific methods helping pesticide applicators make wise decisions when applying all pesticides. One-on-one trainings were conducted by over 45 Extension Agents from 42 county offices across Georgia. Over 1,000 applicators had a unique opportunity to learn more about applying pesticides safely and about UGA Extension during these personal visits. Since the beginning of the UPW training program in 2015, UGA Cooperative Extension has documented a 75% reduction in pesticide drift complaints through 2019. During the 2019 UPW training, farmers representing over two million acres of agricultural land were surveyed along with other clientele. The first two survey questions for all attendees included: 1), Was the UPW training worth your time? and 2), Will this training help you reduce off-target pesticide drift. With greater than an 85% response, over 99% of attendees believed the training was worth their time and the training would help them improve on-target pesticide applications. When farmers were asked specifically to "list your top three most challenging pests", 1,737 growers listed Palmer amaranth 1,773 times with several growers rating this pest as their top 1, 2, and 3 most challenging pests. Morningglory, white flies, dayflower, and sicklepod rounded out the top 5 being listed from 238 times down to 113 times. A final question for farmers asked "What are your three most reliable sources for information regarding weed control and pesticide stewardship?", in which 1,347 farmers listed the UGA Cooperative Extension Service 1,008 times followed by ag-chemical dealers 537 times, crop consultants 188 times, and other growers 147 times.

Sugarcane (*Saccharum* spp. Hybrids) Yield Component Response to Divine Nightshade (*Solanum nigrescens*) Establishment and Removal Timing. Douglas J. Spaunhorst*; USDA-ARS, Houma, LA (033)

Paper withdrawn

Control of Canada Fleabane in Winter Wheat with Postemergence Herbicides. Nader Soltani*, Peter H. Sikkema; University of Guelph, Ridgetown, ON, Canada (034)

This study consisted of six field experiments conducted over a two-year period (2018, 2019) to determine the control of glyphosate-resistant (GR) Canada fleabane with currently available herbicides for winter wheat in Ontario. At 1, 2 and 4 WAA, there was no visible winter wheat injury from any of the herbicides evaluated. Pyrasulfotole/bromoxynil, 2,4-D ester, halauxifen, fluroxypyr/halauxifen + MCPA, pyrasulfotole/bromoxynil/fluroxypyr, pyrasulfotole/bromoxynil/thiencarbazone, pyrasulfotole/bromoxynil/thiencarbazone + MCPA, and fluroxypyr/halauxifen + pyroxsulam + MCPA controlled GR Canada fleabane 94-100% at 8 WAA and reduced density and biomass 95-100% and 97-100%, respectively. Thifensulfuron/tribenuron + fluroxypyr + MCPA, fluroxypyr/bromoxynil/MCPA and tolpyralate controlled GR Canada fleabane 71-84% at 8 WAA and reduced density 88-95% and biomass 86-95%. Pyroxsulam, tribenuron + thiencarbazone, and tribenuron + thiencarbazone + MCPA controlled GR Canada fleabane only 4-33% at 8 WAA and reduced density 61-80% and biomass 21-71% in winter wheat. Reduced GR Canada fleabane interference with pyrasulfotole/bromoxynil/thiencarbazone + MCPA increased winter wheat yield 27% compared to the weedy control. GR Canada fleabane interference had no adverse effect on winter wheat yield with all other treatments. Among herbicide treatments evaluated, herbicide treatments that included pyrasulfotole, halauxifen or 2,4-D provided excellent control of GR Canada fleabane in winter wheat.

Glyphosate in Organic Grain: Exploring Potential Sources of Contamination Through Seed Analysis. Lilianna M. Bento*[1], Barbara Keith[1], Bruce Maxwell[1], Jona Verreth[2], William Dyer[1]; [1]Montana State University, Bozeman, MT, [2]Montana Agriculture Experiment Station Analytical Laboratory, Bozeman, MT (035)

Glyphosate (Roundup® and other commercial names) is the most widely used agricultural herbicide in the world as it is highly efficient at controlling grassy and broadleaf weeds. With the recent advent of Roundup Ready® crops, glyphosate use has increased by 15-fold in the United States alone, because the herbicide can now be used to kill weeds without injuring the crop. As a result, glyphosate residues are now commonly found in many food products. In organic systems, farmers are not allowed to use any synthetic chemicals including glyphosate. However, recent shipments of organic wheat and durum from Montana were determined to be contaminated with glyphosate, causing European buyers to reject them. This has created significant economic hardships for producers in Montana and elsewhere. My research project investigates the potential environmental source(s) of glyphosate contamination in organic wheat. Seven contaminated organic wheat samples were separated into three fractions: germ (embryo), endosperm (flour), and bran (seed coat). I propose three potential sources of contamination: 1) direct glyphosate drift from neighbors' non-organic fields, 2) long-distance aerial transport and deposition during the growing season, and 3) glyphosate deposited on grains during shipping and handling. My hypothesis is that contamination from Source 1 or 2 would result in more glyphosate in the seed germ (embryo), while bran fractions would contain the highest residues if contamination occurred from Source 3. Analysis by the Montana Agriculture Experiment Station Analytical Laboratory using LC-ES/MS/MS (reporting limit of 20 ppb) showed that glyphosate was detected in all three seed fractions, indicating that contamination likely did not come from Source 3. Additional research will be needed to distinguish between Source 1 and 2 as the direct cause of glyphosate contamination in organic grains.

Effective Dicamba Exposure on Enlist Soybean. Julie Reeves*, Sandy Steckel, Clay M. Perkins, Lawrence E. Steckel; University of Tennessee, Jackson, TN (036)

In trying to manage Palmer amaranth, cotton and soybean growers in Tennessee embraced the Xtend (dicamba-tolerant crop) weed management system. In 2017 an estimated 75% of cotton and 60% of soybean acres were planted to Xtend varieties. Unfortunately, most applicators struggled to keep dicamba in the target field when applying this product. The Tennessee Department of Agriculture (TDA) fielded 136 drift complaints. Officials estimated dicamba-drift damages were spread across more than 170,000 off-target hectares – earning Tennessee the undesirable ranking of third in the nation for dicamba damages. Since 2018 there have been fewer official complaints and soybeans acres damaged by off-target dicamba mostly due to the increase in Xtend soybeans being planted in the state. In 2019 it was estimated that well over 90% of the soybeans planted in Tennessee were to an Xtend variety. In 2020 soybean growers will have the choice to plant soybeans with the Enlist trait which provides resistance to glyphosate, glufosinate and 2,4-D. One of the questions Tennessee soybean producers asked about this new trait was if it offered any plant protection against off-target dicamba drift Previous published research would indicate that yield loss from simulated dicamba exposure to Roundup Ready or Liberty Link soybeans would show that yield impact depends upon soybean growth stage at time of exposure, the herbicide rate and how often it was exposed. A study was initiated at Jackson, TN to evaluate if a simulated drift rate of dicamba would affect an Enlist soybean variety. The simulated rate was 1/200 of the field use rate. This rate was sprayed on soybeans at the V3, R1, R3 or R5 growth stages. Other treatments included all applications of that dicamba rate with all combinations of those four growth stages. The treatments were applied with a CO2 back pack sprayer with an application pressure of 275 kpa and calibrated to apply 93 L4/ha. Soybean yield loss was shown with dicamba exposure with all dicamba treatment timings and combinations. The results from this study would suggest that Enlist soybean varieties are just as susceptible to dicamba drift as other non-Xtend varieties. In fact in this study yield loss was demonstrated with the V3 treatment. Previous research has shown that V3 soybean exposed to low rates of dicamba will often not result in yield loss, yet the Enlist soybeans in this study did.

Effect of Herbicides Applied at First Visible Female Inflorescence on Palmer Amaranth (*Amaranthus palmeri*) Fecundity and Seed Viablity. Eric B. Scruggs*, Michael L. Flessner; Virginia Tech, Blacksburg, VA (037)

Palmer amaranth (*Amaranthus palmeri* S.) is a troublesome weed due to its aggressive growth, prolific seed production, and resistance to many herbicides. Effective control at a size greater than 10 cm is difficult. Studies were initiated with the overarching goal of mitigating herbicide resistance by determining the effects of herbicide application at first female inflorescence on weed control, seed production, and viability. Field studies were located in Blackstone and Blacksburg, VA in 2019. Studies were 2 randomized complete block designs with four replications split by soybean variety (Enlist and Xtend). Treatments consisted of: glyphosate, 2,4-D (Enlist), 2,4-D + glyphosate (Enlist), glufosinate (Enlist), glufosinate + glyphosate (Enlist), 2,4-D + glufosinate (Enlist), 2,4-D + glufosinate + glyphosate (Enlist), dicamba (Xtend), dicamba + glyphosate (Xtend), dicamba + glufosinate (Xtend), and dicamba + glufosinate + glyphosate (Xtend). Treatments were used at labeled rates and included adjuvants and nozzles as noted on product labels. Palmer amaranth at these locations were glyphosate and ALS-resistant. 10 Palmer amaranth plants per plot were flagged at first visible female inflorescence directly prior to treatment application and all other weeds were removed. Data collected for both studies included visible control assessed on a 0 (no control) to 100 (plant death) scale four weeks after treatment (WAT), seed production of surviving flagged plants, and soybean yield. All data were subjected to ANOVA and subsequent means separation using Fisher's Protected LSD (a=0.05). Where necessary, data were transformed to improve normality and back transformed data were presented. The most Palmer amaranth control resulted from 2,4-D + glyphosate + glufosinate (94%), 2,4-D + glufosinate (95%), glufosinate + glyphosate (88%), and glufosinate alone (86%) in Enlist soybeans, 4 WAT. 2,4-D applied alone resulted in 62% control and glyphosate alone resulted in 16% control. Similar results were seen in the Xtend treatments, with dicamba + glufosinate + glyphosate (94%), dicamba + glufosinate (93%), and dicamba + glyphosate (87%) performing best. Dicamba alone resulted in 72% control and glyphosate alone resulted in 9% control. All treatments reduced seed production compared to the nontreated in Enlist soybeans. Glyphosate alone reduced seed production 66% and all other treatments reduced seed production 95 to 99.8%. In Xtend soybeans, all treatments besides glyphosate reduced seed production 98 to 99%. There were no differences in yield among treatments. These studies indicate the efficacy of glufosinate, dicamba, and 2,4-D in reducing Palmer amaranth seed production when applied at first visible female inflorescence. Future research will examine cumulative seedling emergence and seed viability from survivors of these treatments. Future research should also investigate delayed applications of glufosinate following auxin herbicides on seed production and alternative timings.

Soybean Response to Multiple Dicamba Exposure. Todd A. Baughman*[1], Robbie Peterson[1], Misha R. Manuchehri[2]; [1]Oklahoma State University, Ardmore, OK, [2]Oklahoma State University, Stillwater, OK (038)

Weed resistance to acetolactate synthase (ALS) and proto-porphyrinogen oxidase (PPO) inhibiting herbicides in addition to glyphosate has become increasingly problematic to Oklahoma growers. This has increased interest in new herbicide technologies like Xtend® Soybean Systems, which are tolerant to dicamba. However, offsite movement could hamper the adoption and use of this technology in the future. Trials were established during the 2018 and 2019 growing seasons at Oklahoma State University's Mingo Valley Research Station near Bixby, OK. Liberty-Link soybean (*Glycine max* L.) were planted on May 22, 2018 and June 13, 2019. Plots were four 76 cm rows by 7.6 m long and included four replications. The center two rows were sprayed with dicamba at 1/1000X (0.56 g ae ha^{-1}) and 1/10,000X (0.00056 g ae ha^{-1}) of the labeled rate. Individual treatments were applied at the V2-V3 growth stage or the R1 growth stage. Treatments were either applied once or followed with two additional applications 7-14 days apart. Plots were maintained weed free throughout the growing season. Visual injury was observed with all treatments of dicamba but varied with rate and timing. Injury never exceeded 5% with the 1/10,000X rate with any application timing in 2018, except with 3 applications starting at the V2 growth stage at 9%. Injury only exceeded 5% with the 1/10,000X rate in 2019 with the 3 applications starting at the V2 growth stage at 11% and the V2 followed by R1 application at 8%. Injury was 5% or less in early September of both years with all treatments applied at the 1/10,000X rate. Injury was at least 15% with all treatments applied at the 1/1000X rate except the single application at the R1 growth stage in 2019. In fact, injury was greater than 20% with the 1/1000X rate when 3 applications were made starting at the V2 growth stage in both 2018 and 2019. Injury in early September was 16 to 24% when dicamba was applied at the 1/1000X rate at the R1 growth stage alone, preceded by the V2 growth stage, or followed by two additional POST applications. Soybean yield was not affected by any of the dicamba treatments in 2018. Yield was also not affected by any of the dicamba treatments applied at the 1/10,000X rate in 2019. Yields were lower with all treatments applied at the 1/1000X rate in 2019 except when applied once at the V2 growth stage. This may have been the result of the 3-week delay with the 2019 planting. Caution should be considered to avoid drift on to susceptible soybean cultivars with delayed planting or double-crop soybean. Interestingly, even with visual injury evaluations as high as 11%, no yield loss was observed with any of the treatments at the 1/10,000X rate, regardless of timing or number of exposures. Visual injury evaluations as high as 20% with the 1/1000X rate did not always translate into a yield loss. However, in cases where visual injury exceeded 20% in 2019, yields compared to the weed-free check did result in a loss. This is further evidence that visual injury does not always correlate with soybean yield losses.

Volunteer Cotton Response to Post Herbicide Applications. Robbie Peterson*, Todd A. Baughman; Oklahoma State University, Ardmore, OK (039)

Volunteer cotton (*Gossypium hirsutum* L.) has developed as a problem with the increase in reduced-tillage and the elimination of in-season cultivation. The lack of winter rainfall in the Southwest reduces deterioration of the seed prior to the next season's planting contributing to this issue. If left uncontrolled volunteer cotton competes for water, nutrient, and light and can lead to problems with harvesting. Trials were conducted at the Oklahoma State University Caddo Research Station near Ft Cobb, OK in 2018 and at the Texas Tech New Deal Research Farm near New Deal, TX in 2019. 2,4-D choline at 1.1 kg ae ha^{-1} or dicamba DGA at 0.56 kg ha^{-1} was applied in their respective technologies. Treatments were applied 1 to 2 leaf, 4 to 5 leaf, square, or bloom. Plots were visually evaluated for volunteer cotton control. Volunteer plant stand counts where collected after harvest. In Oklahoma, 2,4-D visually controlled volunteer cotton 100% late season when applied at the 1-2 or 4-5 leaf growth stage. Volunteer cotton control decreased to 84% when the application was delayed to squaring and 64% when delayed to bloom. Volunteer cotton control in Texas late season was greater than 90% with applications of 2,4-D at the 1-2 leaf and square stage. Control was lower at the 4-5 leaf and bloom stage in Texas. Volunteer cotton control was 91% and 88% when dicamba was applied at the 1-2 or 4-5 leaf stage in Oklahoma. Control decreased to 40% when the dicamba application was delayed to squaring and to 11% when the application was delayed to bloom. Control was highest (75%) when dicamba applications were delayed till squaring in Texas. Volunteer cotton control was 50% or lower with all other application timings of dicamba in Texas. Control was similar between locations with 2,4-D except at the 4-5 leaf growth stage where control was greater in Oklahoma at that timing. Control varied greatly between locations with dicamba where control was greatly improved at the 2 early growth stages in Oklahoma, while the squaring application provided the best control in Texas. When comparing technologies volunteer cotton plant density were lower with 2,4-D herbicide than with dicamba except at the 4-5 leaf stage in Texas. Volunteer plant counts were less than 50% of the untreated with both herbicides and all timings except the Bloom application in Oklahoma. This was not the case in Texas where only 2,4-D applied at the 1-2 leaf growth stage reduced plant density below 50% of the untreated. Volunteer cotton plant density were less than 10% of the untreated with the 1-2 leaf growth stage applications of 2,4-D at both locations and the 4-5 leaf growth stage in Oklahoma. Visual volunteer cotton control was at least 95% when the 1-2 leaf or 4-5 leaf applications were followed by a second application of 2,4-D (both locations) or dicamba (Oklahoma). The multiple applications of 2,4-D reduced volunteer plant density at least 95% compared to the untreated in both Oklahoma and Texas. The only dicamba treatment that had similar results was when the 1-2 leaf application was followed by a 4-5 leaf application in Oklahoma. Yields were at least 120% of the untreated in Oklahoma where acceptable volunteer cotton control was achieved. This indicates that volunteer cotton can not only interfere with harvest but lower yields from a competitive standpoint. Generally, applications should be made early in the season (by the 4-5 leaf growth stage) and in some situations repeat applications may be needed.

Expanding the Vision of Perennial Agriculture with IR-4 Registration in Kernza. Clair L. Keene*[1], Eugene P. Law[2], Jacob Jungers[3], Don Wyse[3], Valentin Picasso[4], David E. Stoltenberg[4]; [1]North Dakota State University Extension, Williston, ND, [2]Cornell University, Ithaca, NY, [3]University of Minnesota, Saint Paul, MN, [4]University of Wisconsin-Madison, Madison, WI (040)

Perennial grains have the potential to shift the paradigm of agriculture from one based on disturbance to one rooted in continuous living cover. Kernza® is intermediate wheatgrass (*Thinopyrum intermedium*) bred for increased seed yield and is the first perennial grain brought to market in the US. Kernza acres are limited but market potential of the crop is large. To increase adoption of perennial crops, chemical weed control options are needed but human-food use of Kernza grain is not covered under herbicides currently labeled for use in forage-type intermediate wheatgrass. To address this, field trials are underway in North Dakota, Minnesota, Wisconsin, and New York to support IR-4 approval of herbicides in Kernza.

Evaluation of PRE and POST Applications of Metribuzin on Weed Control Programs in Corn (*Zea mays*). Taghi Bararpour*, Ralph R. Hale, M. W. Ebelhar; Mississippi State University, Stonevill, MS (041)

Abstract not available

Burndown Residual Herbicide Plus Halauxifen-Methyl (Elevore) for Early Preplant Horseweed (*Conyza canadensis*) Control. Taghi Bararpour*[1], Ralph R. Hale[1], Larry C. Walton[2], Henry M. Edwards[1]; [1]Mississippi State University, Stoneville, MS, [2]Corteva, Tupelo, MS (042)

Horseweed (*Conyza canadensis*) is a winter annual weed that is problematic in many agricultural systems, particularly no-till systems. In Mississippi, there are populations of horseweed that are resistant to glyphosate or paraquat, or both. A field study was conducted in 2019 at the Delta Research and Extension Center, in Stoneville, Mississippi, to evaluate pre-plant burndown residual herbicide Plus halauxifen-methyl (Elevore) on horseweed control. At the time of herbicide applications there were three horseweed sizes: 5- to 6-, 6- to 7-, and 7- to 8-inches. Soybean (LibertyLink) was planted on June 4 and emerged on June 10. Herbicide applications were made on April 29. All herbicide rates are in kg ai ha^{-1}. Treatments were arranged in a randomized complete block design. Herbicide treatments included: 1) halauxifen-methyl at 0.005 + rimsulfuron at 0.018 + thifensulfuron at 0.018 + glyphosate at 1.12; 2) halauxifen-methyl + flumioxazin at 0.07 + thifensulfuron at 0.009 + DPX-L5300 at 0.009 + glyphosate; 3) halauxifen-methyl + DPX-L8347 at 0.21 + glyphosate; 4) halauxifen-methyl + rimsulfuron + thifensulfuron at 0.018 + glyphosate + 2,4-D at 0.533; 5) halauxifen-methyl + flumioxazin + thifensulfuron at 0.009 + DPX-L5300 + glyphosate + 2,4-D 0.533; 6) halauxifen-methyl + DPX-L8347 + glyphosate + 2,4-D at 0.533; 7) rimsulfuron + thifensulfuron at 0.018 + glyphosate + 2,4-D at 1.07; 8) flumioxazin + thifensulfuron at 0.009 + DPX-L5300 + glyphosate + 2,4-D at 1.07; 9) DPX-L8347 + glyphosate + 2,4-D at 1.07; 10) glyphosate + 2,4-D at 0.533; 11) glyphosate + 2,4-D at 1.07;12) rimsulfuron + thifensulfuron at 0.018 + glyphosate; 13) flumioxazin + thifensulfuron at 0.009 + DPX-L5300 + glyphosate; 14) DPX-L8347 + glyphosate; 15) glyphosate; 16) halauxifen-methyl; and 17) glyphosate + halauxifen-methyl. All treatments were applied with a methylated seed oil (MSO) at 1% v/v. An untreated check was added for comparison. All treatments [except treatments 15 (38%)] provided 90 to 100% control of 5- to 6-inch horseweed by 35 days-after application (DAA). Treatments 13 (84%), 14 (83%), and 15 (40%) failed to control 6- to 7-inches horseweed >85%. All other treatments provided 90 to 100% control of 6- to 7-inch horseweed. Horseweed = 7 inches were difficult to control. Only treatments 9 provided 91% control of 7- to 8-inch horseweed 35 DAA. Horseweed (= 7 in) control was 86, 79, 88, 85, 81, 89, 88, 85, 91, 88, 89, 79, 73, 71, 14, 80, and 84% from treatments 1 through 17, respectively. Overall, treatment 9 (DPX-L8347 + glyphosate + 2,4-D) provided 100% control of 5- to 7-inches horseweed and 91% control of 7- to 8-inches horseweed. However, halauxifen-methyl provided comparable results as treatment 9. There was no soybean injury 7- to 28-days after emergence. Therefore, halauxifen-methyl may be another option in controlling glyphosate-resistant horseweed.

Does Late Season Weed Cover Reduce Corn Silage Yield and Alfalfa Establishment in Interseeded Corn/Alfalfa Systems? Jose Luiz Carvalho de Souza Dias*, Mark J. Renz; University of Wisconsin-Madison, Madison, WI (043)

Interseeding alfalfa (*Medicago sativa L.*) into corn silage (*Zea mays L.*) has several advantages compared with traditional corn-alfalfa rotation systems, including greater first year alfalfa DMY and ground cover during and after corn production. However, late season weed control can be difficult to achieve in these systems. As the effects of late-season weed interference on silage corn yield and alfalfa establishment is not known, we investigated this potential impact on sixteen locations across four different states (WI, MI, PA, and ID) in 2018 and 2019. Corn silage yield and fall alfalfa plant density were measured at each location. Total weed cover was visually estimated during late July. Data were from structured experiments including two alfalfa weed management systems (conventional and Roundup Ready [RR]) and four different agrochemical strategies targeted to improve alfalfa establishment (Untreated, Prohexadione-calcium [PHD], fungicide [F; pyraclostrobin + fluxapyroxad] and insecticide [I; lambda-cyhalothrin + benzisothiazolin] and PHD+FI). Mixed-effects models were utilized to determine if factors resulted in different fall alfalfa plant density (October), silage corn yield (normalized to weed-free corn-only plots) and interacted with weed cover (covariate). As initial alfalfa stand varied, sites were classified in the spring as poorly (less than 161 plants m^{-2}) or well established (more than 161 plants m^{-2}) and added as a fixed factor. Significant ($p<0.05$) weed cover effects were modeled using linear regressions when appropriate. Results indicated that late-season weed cover may negatively impact alfalfa fall density, but responses depended on the initial alfalfa stand. In interseeded fields with low initial stand, alfalfa fall density decreased by 21 plants m^{-2} for every weed cover increase in 10% ($p<0.01$), averaged across alfalfa cultivars and agrochemical strategies. Likewise, alfalfa plant density decreased as weed cover increased in fields with high initial alfalfa stand ($p<0.01$). However, linear regression did not result in a significant slope. Late-season weed cover also had a negative impact on corn silage yield but only in areas with poor initial alfalfa stands ($y = 92.5 - 0.172 x$; $p<0.01$). Our findings indicate that late-season weed cover can be detrimental to both alfalfa establishment and silage corn yield in corn-alfalfa interseeded systems. Since late-season weed cover impacts were more pronounced when initial alfalfa stands were low, good management practices that maximize alfalfa establishment should be emphasized in this system to minimize interference from late-season weeds.

Field Bindweed (*Convolvulus arvensis*) Management in California Cotton. Kurt J. Hembree*; University of California Cooperative Extension, Fresno, CA (044)

Field bindweed (*Convolvulus arvensis*) is a deep-rooted member of the Convolvulaceae that is native to the Mediterranean region; the species was first formally reported in California in 1850 (San Diego) and has been problematic in various crop production systems since that time. While foliar-applied systemic herbicides (in groups WSSA 4, WSSA 9) are traditionally used for suppression, several soil applied products (in groups WSSA 2, WSSA 3 and WSSA 14) have shown some activity against emerging, perennial vines. Between 2013 and 2019, several studies were undertaken to evaluate the effects on trifluralin, rimsulfuron and sulfentrazone on field bindweed suppression in processing tomato, Pima cotton, and under bare-ground conditions. With respect to tomato, field bindweed cover at 4 weeks after treatment (WAT) in the trifluralin (applied PPI as Treflan at 32 oz/A), rimsulfuron (PRE as Matrix at 4 oz/A) and sulfentrazone (PRE as Zeus at 3.2 to 6 oz/A) was averaged across five individual studies; field bindweed cover in the UTC was 51%. In Pima cotton, bindweed cover in trifluralin (PPI as Treflan at 24 oz/A) treated plots ranged from 16 to 44% at 4 WAT; cover in plots that did not receive trifluralin PPI ranged from 34 to 51%. Where trifluralin was followed by glyphosate (POST as Roundup Powermax at 32oz/A), cultivation, or glyphosate followed by cultivation, bindweed cover ranged from 5 to 20% at 8 WAT. Where glyphosate and cultivation were used, alone, bindweed cover ranged from 51 to 54% at 8 WAT; cover in plots treated with glyphosate followed by cultivation (in the absence of trifluralin PPI) was 7% at 8 WAT. Field bindweed cover was greatest at 8 WAT where trifluralin was used in the absence of any POST weed management strategy (59%) and in the untreated check (75%). In bare ground studies comparing the performance of orchard herbicides for weed suppression, rimsulfuron (PRE as Matrix at 4 oz/A) and sulfentrazone (PRE as Zeus at 6 to 12 oz/A) alone and in combination were the only herbicides able to suppress perennial bindweed emergence in the late April following dormant-season treatments. 50% fewer bindweed vines had emerged (<3 per m^2) as compared to the untreated check, indaziflam (PRE as Alionat 3.5 to 5 oz/A), and penoxsulam plus oxyfluorfen (PRE aPindar GT at 2.5 to 3 pt/A) where cover ranged from 5 to almost 7 vines per m^2. To control field bindweed, repeated, foliar-applied systemic herbicide treatments are often necessary, although trifluralin, rimsulfuron and sulfentrazone have demonstrated short-term suppressive capabilities. While herbicides are important tools for managing this problematic species, non-chemical and integrated approaches should also be explored.

Cereal Rye Termination Timing and Method Influence Glyphosate-Resistant Horseweed (*Erigeron canadensis*) Suppression in Sugarbeet. Brian J. Stiles II*, Christy Sprague; Michigan State University, East Lansing, MI (045)

Michigan sugarbeet farmers rely heavily on the use of glyphosate for weed control. However, glyphosate-resistant (GR) horseweed (*Erigeron canadensis* L.) poses a major challenge in this system, leaving only one option (clopyralid) for control of this problematic weed. Cover crops have been implemented into other cropping systems to suppress weeds and may provide an additional option to improve horseweed management in sugarbeet. In 2019, a field study was conducted in East Lansing, Michigan to evaluate the effects of GR horseweed suppression in response to termination time and method of fall-planted cereal rye, combined with different POST herbicide treatments for horseweed control. Cereal rye was drilled at 67 kg ha^{-1} on November 8, 2018. The study was arranged in a split-plot design with cereal rye termination method and time as the main plot factor and herbicide treatment as the sub-plot factor. Cereal rye treatments included: 1) early burndown (14 EPP) 14 d prior to sugarbeet planting, 2) burndown at planting (at plant), 3) at planting burndown followed by a land-roller, 4) at planting burndown followed by a roller crimper, 5) delayed burndown ('Planting Green') 14 d after planting, and a 6) no cover control. The burndown application consisted of glyphosate applied at 1.22 kg ae ha^{-1} + ammonium sulfate. The three herbicide treatments consisted of two POST applications at the 2- and 6-8 leaf sugarbeet stage. The treatments included: 1) glyphosate twice 1.22 followed by 0.84 kg ae ha^{-1} (control), 2) glyphosate followed by glyphosate + clopyralid (0.11 kg ha^{-1}) and 3) glyphosate + clopyralid (0.06 kg ha^{-1}) followed by glyphosate + clopyralid (0.11 kg ha^{-1}). Cereal rye biomass at the time of the 'Planting Green' termination was 5-times higher (4,200 kg ha^{-1}) than biomass harvested at the 14 EPP and at plant burndown treatments which were 640 and 740 kg ha^{-1}, respectively. Horseweed biomass 14 d after planting (DAP) was 11 times lower where a cover crop was planted compared with the no cover control, regardless of termination time or method. 'Planting Green' with an application of clopyralid applied either once or twice reduced horseweed biomass up to 99%. Horseweed biomass was lower than the no cover crop control for all of the other treatments, except the one application of clopyralid without a cereal rye cover crop. At harvest, the main effect of cereal rye reduced horseweed biomass up to 75% compared with the no cover control. Overall the at plant, at plant + roller crimper and 'Planting Green' termination methods reduced horseweed biomass more than the other termination methods. While the 'Planting Green' termination method provided the greatest suppression of horseweed it did not translate into higher sugarbeet yields. 'Planting Green' reduced sugarbeet growth resulting in a 42 and 52% in yield and recoverable white sucrose, respectively, compared with the other termination methods and was not different than the no cover control. Sugarbeet yield and recoverable white sucrose was highest with the at plant and the at plant + roller cereal rye termination. Sugarbeet yields for the 14 EPP and at plant + roller crimper termination methods were similar to the at plant + roller termination method. Sugarbeet yield was 33% higher with the at plant burndown + clopyralid applied twice compared with no cover control + clopyralid twice. Integrating cereal rye to suppress horseweed in sugarbeet production systems have shown positive results, however it will be important to examine further how these strategies can be refined to improve horseweed suppression, while maintaining sugarbeet yield.

Roughstalk Bluegrass (*Poa trivialis*) Control in Winter Wheat. Gary Edward Powell*, Brian J. Stiles II, Christy Sprague; Michigan State University, East Lansing, MI (046)

In recent years, roughstalk bluegrass has become a problem weed in Michigan winter wheat fields. It is a perennial grass species that propagates through aboveground stolons, and by seed that can germinate in both the fall and spring. Our research indicates that in wheat, roughstalk bluegrass spreads mainly by seed. Research trials were conducted in 2017 near Deckerville, and in 2018 and 2019 in East Lansing MI, to evaluate roughstalk bluegrass control in winter wheat. Roughstalk bluegrass time of emergence; fall, early spring, or late spring, was highly variable each year. In 2017, spring applications of mesosulfuron, pyroxsulam, and pinoxaden applied early postemergence (EPOS) and postemergence (POST) resulted in 100% roughstalk bluegrass control, 56 d after treatment (DAT); while spring applications of propoxycarbazone applied EPOS and POST resulted in 100 and 55% control, respectively. In 2018, fall POST applications of mesosulfuron, pyroxsulam, and pinoxaden resulted in over 90% control in early May; however, by early June control was lower at 87, 79 and 75%, respectively. Spring EPOS applications of mesosulfuron, pyroxsulam, and pinoxaden provided 100, 77, and 94% control, respectively, while applications of these herbicides made two weeks later POST resulted significantly lower control (79, 25, and 80%). In 2019, EPOS applications of mesosulfuron, pyroxsulam, pinoxaden, pinoxaden + fenoxaprop resulted in 98, 94, 97, and 99% control, respectively, 28 DAT. The addition of bromoxynil + pyrasulfotole as a tank-mix partner did not affect roughstalk bluegrass control in 2018 and 2019. Roughstalk bluegrass reduced winter wheat yield up to 50% in the untreated control compared with fall or EPOS treatments of mesosulfuron, pyroxsulam, and pinoxaden. From our research mesosulfuron applied EPOS to roughstalk bluegrass 2-5 cm tall has provided the most consistent control. Later spring herbicide applications should be avoided due to poorer control and yield reductions due to roughstalk bluegrass competition.

Comparison of Herbicide Programs in Conventional, Glufosinate, and Glyphosate/Dicamba-Resistant Soybeans Across Nebraska. Adam Striegel*[1], Stevan Knezevic[2], Nevin Lawrence[3], Gary Hein[1], Greg R. Kruger[4], Chris Proctor[1], Kent Eskridge[1], Amit J. Jhala[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Concord, NE, [3]University of Nebraska-Lincoln, Scottsbluff, NE, [4]University of Nebraska-Lincoln, North Platte, NE (047)

Field experiments were conducted in 2018 and 2019 at three irrigated (south-central, west-central, western) and two rain-fed locations (northeastern and eastern Nebraska) to evaluate three-way premixed PRE herbicide programs fb POST herbicide programs for weed control, crop yield, gross profit margin, and benefit-cost ratio. Experiments were arranged in a split-block design with five PRE herbicide programs, nontreated control, and weed free check as the whole plot factor, with conventional and herbicide-resistant soybean cultivars and four POST herbicide programs as the subplot arranged in strips. At 28 d after PRE (DAPRE), sulfentrazone/s-metolachlor plus metribuzin, chlorimuron/flumioxazin/thifensulfuron-methyl, flumioxazin/pyroxasulfone plus metribuzin, chlorimuron/flumioxazin/metribuzin, and imazethapyr/pyroxasulfone/saflufenacil preformed similarly, providing 99-85% control of common lambsquarters (*Chenopodium album* L.), kochia [*Bassia scoparia* (L.) A. J. Scott], Palmer amaranth (*Amaranthus palmeri* S. Watson), velvetleaf (*Abutilon theophrasti* Medik.), and a mixture of foxtail (*Seteria* spp.) and other *Poaceae* species. Most PRE programs provided >80% weed biomass reduction and >75% weed density reductions 1d before POST preforming similarly to weed free checks at all locations. Similarly, at 28 d after POST (DAPOST) glyphosate plus dicamba, glyphosate, glufosinate and lactofen plus clethodim plus acetochlor provided 93-99% control at 28 DAPOST for all weed species excluding kochia, with lactofen plus clethodim plus acetochlor, glufosinate, glyphosate, and glyphosate plus dicamba providing 29, 74, 74, and 91% control respectively at the west-central location. All POST herbicide programs provided >85% weed biomass reduction >90% density reductions at 28 d after POST (DAPOST). For combined site years, crop yield for most PRE herbicide programs across all POST herbicide programs were similar to the weed free check (4,015 kg ha^{-1}) excluding chlorimuron/flumioxazin/thifensulfuron-methyl (3,740 kg ha^{-1}) and chlorimuron/flumioxazin/metribuzin (3,700 kg ha^{-1}). Likewise, crop yield for POST herbicide programs across all PRE herbicide programs in combined site years were similar with the exception of lactofen plus clethodim plus acetochlor (3,147 kg ha^{-1}). While crop yield for conventional and herbicide-resistant cultivars were similar for most PRE fb POST programs, the gross profit margin in glyphosate/dicamba-resistant and glufosinate-resistant cultivars were the higher than conventional cultivars, with benefit-cost ratios ranging from 2.81-3.13 for glyphosate/dicamba-resistant cultivars receiving glyphosate plus dicamba POST, 2.94-3.77 for glyphosate/dicamba-resistant cultivars receiving glyphosate POST, 2.63-3.25 for glufosinate-resistant cultivars receiving glufosinate POST, and 1.38-1.81 for conventional cultivars receiving lactofen plus acetochlor plus clethodim POST. Results of this study indicate glufosinate-resistant and glyphosate/dicamba-resistant cultivars provide similar economic returns.

Herbicide Resistant Italian Ryegrass (*Lolium perenne* Ssp. *multiflorum*) Survey in Northern Idaho and Eastern Washington. Traci Rauch*, Joan M. Campbell; University of Idaho, Moscow, ID (048)

The Pacific Northwest of the United States is a productive wheat growing region with significant yield loss from annual grass weeds. Persistent use of herbicides with the same modes of action has resulted in the selection of many herbicide-resistant weeds. Resistance to herbicides used for annual grass control is a problem for farmers in the region. A survey of 95 fields in the Palouse region of the inland Pacific Northwest was conducted to determine the extent of Italian ryegrass resistance to grass herbicides commonly used in winter wheat-cropping systems. Plants were grown from collected seed samples in a greenhouse and were tested for resistance to quizalofop, sethoxydim, clethodim, pinoxaden, mesosulfuron, pyroxsulam, and glyphosate. Quizalofop, sethoxydim, clethodim are ACCase-inhibiting herbicides that are non-selective to grass crops and resistance was observed in 77, 57, and 23%, respectively, in the populations tested. This is a large increase compared to a survey of 75 fields in the same region in 2007, where quizalofop, sethoxydim and clethodim resistance was 48, 18, and 13%, respectively. Resistance to pinoxaden, an ACCase-inhibiting herbicide used in wheat and barley, occurred in 74% of the populations tested in 2018 compared to 31% in the 2007 survey. Mesosulfuron and pyroxsulam (ALS-inhibiting-herbicides used in wheat) resistance was found in 90 and 89% of the populations. In the 2007 survey, mesosulfuron resistance occurred in 34% of the populations. All populations tested were susceptible to glyphosate. Populations susceptible to both ALS-inhibiting herbicides occurred at 9%, while populations susceptible to all four ACCase-inhibiting herbicides occurred at 6%. Only 6% of populations were completely susceptible to all 7 herbicides tested. These results indicate that herbicide-resistant Italian ryegrass populations are increasing across much of the Palouse region in northern Idaho and eastern Washington.

Glyphosate-Tolerant Soybean Yield Loss and Yield Response to Micro-Rates of 2,4-D as Influenced by Growth Stage. Ivan B. Cuvaca*[1], Stevan Knezevic[2], Jon Scott[1], Darko Jovanovic[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Concord, NE (049)

With the introduction of 2,4-D-tolerant crops, the use of 2,4-D and the risk of drift in non-2,4-D tolerant crops including soybean are likely to increase. To understand the impact of 2,4-D drift on glyphosate-tolerant (GT) soybean, a study using a randomized complete block design with four replications and a split-plot arrangement of treatments was conducted in 2019 near Concord, NE. Main plots consisted of three 2,4-D pplication times [second trifoliate (V2); beginning of flowering (R1); and full flowering (R2)] and subplots consisted of six micro rates of 2,4-D (1/5; 1/10; 1/50; 1/100; 1/500; and 1/1000 of the label recommended dose of 1,120 g ae ha^{-1}) and a check with no herbicide applied. Soybean injury was visually assessed at 7, 14 and 21 days after treatment (DAT).

Grain yield was also collected using a small-plot combine. In general, there was an increase in soybean injury and reduction in grain yield with increase in 2,4-D dose. GT soybean was more sensitive to 2,4-D injury at reproductive (R2 and R1) than vegetative (V2) stage. Less than 1/10 of the label recommended dose of 2,4-D caused 5-20% injury to GT soybean. Based on estimates of the effective dose of 2,4-D required to cause 5% injury, GT soybean was 1.2- and 1.4-fold more sensitive to 2,4-D at R2 (44.88 g ae ha^{-1}) than R1 (53.12 g ae ha^{-1}) and V2 (61.78 g ae ha^{-1}) stage,respectively. This increase in GT soybean sensitivity to 2,4-D injury has ultimately resulted in a significant reduction in grain yield especially at the R2 stage. Preliminary data analysis showedthat 2,4-D dose of 0.33 g ae ha^{-1} reduced GT soybean yield at R2 by 5% (0.22 Mg ha^{-1}) compared with 1.77 and 54.58 g ae ha^{-1} at the R1 and V2 stage, respectively. These results show that 2,4-D drift poses a risk to GT soybean and can result in significant yield losses; therefore, it is crucial that 2,4-D drift is prevented especially at reproductive stage(s).

Effect of Growth Stage on Glyphosate-Tolerant Soybean Sensitivity to Micor-Rates of 2,4-D. Ivan B. Cuvaca*[1], Jon Scott[1], Darko Jovanovic[1], Stevan Knezevic[2]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Concord, NE (050)

Off-target movement of 2,4-D can cause severe injury to susceptible crops including non-2,4-D tolerant crops. A field study was conducted in 2019 near Concord, NE to investigate the effect of growth stage on glyphosate-tolerant (GT) soybean sensitivity to micro-rates of 2,4-D. The experiment used a randomized complete block design (RCBD) with eight replications and a split-plot arrangement. Main plots consisted of three 2,4-D application times [second trifoliate (V2); beginning of flowering (V7/R1); and full flowering (R2)] and subplots consisted of six micro rates of 2,4-D (1/5; 1/10; 1/50; 1/100; 1/500; and 1/1000 of the label recommended dose of 1,120 g ae ha^{-1}) and a check with no herbicide applied. Soybean injury assessment and plant height measurements were performed at 7, 14 and 21 days after treatment (DAT). Number of days to canopy closure was also recorded. In general, increase in 2,4-D dose increased soybean injury and reduced plant height. Less than 1/10 of the label recommended dose of 2,4-D caused5-20% injury to GT soybean regardless of application time; however, GT soybean was more sensitive to 2,4-D injury at reproductive (R2 and R1) than vegetative (V2) stage. A 2,4-D dose of 44.88 g ae ha^{-1} caused 5% injury to GT soybean at the R2 stage compared with a 1.2- and 1.4-fold higher dose required to cause the same level of injury at the R1 and V2 stage, respectively. Plant height, on the other hand, was more sensitive to 2,4-D at R1 than the V2 and R2 stages. A dose of 2,4-D of 6.93 g ae ha^{-1} reduced plant height at R1 by 5% (3.7 cm) compared with a 1.5 (10.29 g ae ha^{-1}) to 1.6 (11.22 g ae ha^{-1})-fold higher dose that was required to cause the same reduction in plant height at other growth stages. Because of this increase in GT soybean injury and reduction in plant height, there was a delay in canopy closure with a 2,4-D dose of 9.76, 3.53 and 3.81 g ae ha^{-1} resulting in a 5 day delay in canopy closure at V2, R1 and R2 stage, respectively. Altogether, these results show that GT soybean is sensitive to micro-rates of 2,4-D especially at the reproductive stages.

Effects of Dicamba Ultra Micro-Rate on Soybean Yield – Hormesis or Not? Stevan Knezevic*; University of Nebraska-Lincoln, Concord, NE (051)

There are speculations that a drift of sub-lethal or ultra-low doses of dicamba herbicides to soybean can increase the yield through the phenomenon called hormesis. Thus, there is a need to evaluate the impact of ultra micro-rates of dicamba on yields of sensitive soybean. Field study was conducted in 2018 and 2019 at Concord, NE. The study was arranged as a split -plot design with ten dicamba micro-rates, 3 application times and 4 replications. Dicamba rates included 0; 1/10; 1/100; 1/1000; 1/5000; 1/10000; 1/20000; 1/30000; 1/40000 and 1/50000 of the 560 g ae ha^{-1} (label rate) of XtendiMax. The 3 application times were V2 (2nd trifoliate), R1 (beginning of flowering) and R2 (full flowering) stages of soybean development. Application of 1/5000 to 1/10 of dicamba label rate caused 20 to 80% visual injury with the greatest injury at R1. A 1/10 of the dicamba label rate could cause 23 to 78% soybean yield loss depending on the growth stage of exposure; with the greatest yield loss (78%) at the R1 stage. In general, our preliminary study suggested that there was no evidence that sub-lethal doses of dicamba could increase the yield of soybean irrespective of the growth stage of dicamba exposure, suggesting that there is no hormesis occurring.

Growth and Sensitivity of Diamba-Tolerant Soybean to Micro-Rates of 2,4-D. Stevan Knezevic*[1], Jon Scott[2], Darko Jovanovic[2], Ivan B. Cuvaca[2]; [1]University of Nebraska-Lincoln, Concord, NE, [2]University of Nebraska-Lincoln, Lincoln, NE (052)

2,4-D is prone to drift. This raises a concern regarding potential damage to non 2,4-D-tolerant soybean. The objective of this study was to investigate the impact of 2,4-D micro-rates ongrowth and sensitivity of dicamba-tolerant (DT) soybean. A randomized complete block design with a split-plot arrangement and eight replications was used. Main plots consisted of three 2,4-D application times [second trifoliate (V2); beginning of flowering (R1); and full flowering (R2)] and subplots consisted of six micro rates of 2,4-D (1/5; 1/10; 1/50; 1/100; 1/500; and 1/1000 of the label recommended dose of 1,120 g ae ha^{-1}) and a check with no herbicide applied. Visual injury assessment and plant height measurement were performed at 7, 14 and 21 days after treatment (DAT). Number of days to canopy closure was also recorded. Increase in 2,4-D dose increased soybean injury and reduced plant height regardless of application time. Soybean was 1.9- and 2.6-times more sensitive to 2,4-D injury at V2 and R2 stage, respectively, than the R1 stage; however, plant height reduction at the R1 stage was 4.4- and 2.6-fold that of the V2 and R2 stage, respectively. This reduction in plant height ultimately delayed canopy closure. For example, 0.89 g ae ha^{-1} of 2,4-D delayed canopy closure at R1 stage by 5 days and a 3.8 (3.40 g ae ha^{-1})- and 5.7 (5.09 g ae ha^{-1})-fold higher dose was required to delay canopy closure by same number of days (eg. 5 days) at the V2 and R2 stage, respectively. Leaf curling was more severe at both R1 and R2 than the V2 stage. Altogether, these results show that DT soybean is sensitive to micro-rates of 2,4-D especially at the onset of the reproductive stage (R1). Therefore, late 2,4-D applications should be avoided to prevent potential interference with pod formation and ultimately yield.

Weed Management Systems in Imidazolinone Tolerant Grain Sorghum in South Texas. Alvaro Garcia*[1], Joshu A. McGinty[2], Jamie Foster[3], Greta Schuster[1], Alinna Umphres[1], Paul A. Baumann[4]; [1]Texas A&M University, Kingsville, TX, [2]Texas A&M AgriLife Extension, Corpus Christi, TX, [3]Texas A&M AgriLife Research, Corpus Christi, TX, [4]Texas A&M AgriLife Extension, College Station, TX (053)

With limited herbicide options and the lack of herbicide tolerance in grain sorghum (*Sorghum bicolor* [L.] Moench), weed management remains a challenge. The recent development of imidazolinone-tolerant hybrids has created an opportunity for exploring the uses of herbicides previously unavailable for use in this crop. Field trials were conducted in 2019 to investigate: 1) the efficacy of imazamox alone applied postemergence (POST), or applied preemergence (PRE) or POST as a component of a diverse herbicide program for controlling key weed species, 2) examine the impacts of weed competition on grain yield. These trials included twelve herbicide treatments arranged as a randomized complete block with four replications (4 [96-cm] rows x 9.1 m). This study was conducted at three locations in South Texas; Beeville, Corpus Christi, and Kingsville. Treatments included imazamox alone or in combination with herbicides such as atrazine, prosulfuron, dimethenamid, and pyrasulfotole + bromoxynil. Imazamox at either 53 or 79 g ai ha^{-1} applied POST to grass weeds 5 to 8 cm in height resulted in some of the lowest amounts of late-season weed biomass among treatments in this study. The same rates of imazamox applied to grass weeds 13 to 15 cm in height were not as effective. Atrazine PRE followed by atrazine + prosulfuron POST had little effect suppressing Texas panicum (*Urochloa texana)* but with the addition of imazamox POST, density was significantly reduced at both 14 and 28 DAT. Grass control was greatest with atrazine + dimethenamid PRE followed by atrazine + imazamox POST. This treatment also resulted in some of the highest grain yields, while the lowest yielding were the NTC and atrazine PRE followed by atrazine + prosulfuron POST. These results show that the addition of imazamox to herbicide programs in grain sorghum can improve the control of key weed species.

Herbicidal Activity of a New Pyridine Derivative M-862 on Broadleaf Weeds and Wheat.
Nam-Gyu Cho*[1], Dae-Won Koo[1], Ki-Hwan Hwang[1], Suk-Jin Koo[2]; [1]Moghu Research Center, Ltd., Yuseong, Daejeon, South Korea, [2]Moghu Research Center, Ltd., Daejeon, South Korea (054)

M-862 (methyl 4-amino-3-chloro-6-(3-chloro-4,5-dihydroisoxazol-5-yl)picolinate) is a new auxin herbicide candidate discovered by Moghu Research Center and Korea Research Institute of Chemical Technology. This study was conducted to evaluate the properties of M-862 in terms of herbicidal spectrum to various broadleaf weeds and phytotoxicity to wheat in greenhouse and field. The tests were conducted during 2018 and 2019 in South Korea. M-862 provided >90% control of the most broadleaf weeds at 100 to 200 g ha^{-1}, and especially complete control of cleaver (*Galium spurium*) at <10 g ha^{-1}, whereas it showed little to no phytotoxicity on wheat up to 800 g ha^{-1}.

Rapid Spread of Glyphosate-resistant Kochia [*Bassia scoparia* (L.) A.J.Scott] in Manitoba.
Charles M. Geddes*[1], Teandra Ostendorf[1], Robert Gulden[2], Tammy Jones[3], Julia Leeson[4], Scott Shirriff[4], Shaun Sharpe[4], Hugh J. Beckie[5]; [1]Agriculture and Agri-Food Canada, Lethbridge, AB, Canada, [2]University of Manitoba, Winnipeg, Canada, [3]Manitoba Agriculture, Carman, MB, Canada, [4]Agriculture and Agri-Food Canada, Saskatoon, SK, Canada, [5]University of Western Australia, Crawley, Australia (055)

Kochia [*Bassia scoparia* (L.) AJ.Scott] is the first known glyphosate-resistant (GR) weed species in western Canada. In 2011, the first confirmations of GR kochia were from chemical-fallow fields located in Warner County, Alberta. Baseline surveys conducted in 2012 (Alberta) and 2013 (Manitoba and Saskatchewan), identified glyphosate resistance in 5%, 5% and 1% of kochia populations in Alberta, Saskatchewan and Manitoba, respectively. Unlike Alberta and Saskatchewan, the first confirmations of GR kochia in Manitoba were in the GR crops, corn and

soybean. A follow-up randomized stratified survey of herbicide-resistant kochia was conducted in Manitoba in 2018 using the same methods as the 2013 baseline survey (but different sample locations). Kochia samples were collected post-harvest from 297 predetermined (township-scale) locations in Manitoba in October. Kochia seed was harvested, and seedlings were grown in the greenhouse and treated with a discriminating dose of glyphosate (Roundup WeatherMax, 540 g a.e. L^{-1}, 900 g a.e. ha^{-1}) when they were 3 to 5 cm tall. Plants were rated visually as susceptible (dead or nearly dead) or resistant (some injury but new growth, or no injury) 3 weeks after application. After five years, the incidence of glyphosate resistance increased from 1% to 59% of kochia populations in Manitoba. Unlike the 2013 survey, GR kochia was confirmed in a range of field crops, including soybean (77% of kochia populations), corn (70%), canola (53%), other oilseeds (83%), small-grain cereals (48%), pulses (20%), alfalfa/grass (50%), and ruderal areas (21%). The rapid increase of GR kochia in Manitoba coincides with similar observations in Alberta. Growers will need to shift their kochia management programs to compensate for the lack of efficacy of this important herbicide. These management programs will consist of increased reliance on alternative herbicide sites-of-action pre-emergence, adoption of herbicide-resistant crops with stacked resistance traits, and integration of non-chemical tools into current weed control programs.

Characterization of Dicamba- and Fluroxypyr-resistant Kochia [*Bassia scoparia* (L.) A.J.Scott] in Alberta. Charles M. Geddes*[1], Mallory Owen[1], Elise Martin[2], Linda Hall[2], Scott Shirriff[3], Julia Leeson[3], Hugh J. Beckie[4]; [1]Agriculture and Agri-Food Canada, Lethbridge, AB, Canada, [2]University of Alberta, Edmonton, AB, Canada, [3]Agriculture and Agri-Food Canada, Saskatoon, SK, Canada, [4]University of Western Australia, Crawley, Australia (056)

A recent 2017 survey confirmed dicamba resistance in 18% of kochia [*Bassia scoparia* (L.) A.J.Scott] populations in Alberta, while 10% were triple-resistant to tribenuron/thifensulfuron, glyphosate and dicamba. This followed the first confirmation of auxinic herbicide-resistant kochia in western Canada found in a spring wheat field in Saskatchewan (in 2015). While the initial auxin-resistant kochia population exhibited resistance to both dicamba and fluroxypyr, the Alberta populations were tested with dicamba only. Auxinic herbicide cross-resistance in kochia populations would leave growers with limited herbicide options, especially in small-grain cereal crops. The objective of this study was to characterize resistance to the synthetic auxin herbicides dicamba and fluroxypyr in Alberta kochia populations. Dicamba and fluroxypyr dose-response experiments were used to study 17 kochia populations, including one dicamba- plus fluroxypyr-resistant control and four susceptible controls. The herbicide dose required to reduce fresh weight biomass by 50% relative to the untreated control (GR50) ranged among kochia populations from 36 to 314 g ai ha^{-1} for dicamba, and 3 to 916 g ai ha^{-1} for fluroxypyr. Excluding the controls, ten of the twelve kochia populations were confirmed dicamba-resistant; three with high-level resistance [resistant to susceptible ratio (R/S) of 4.0 to 5.3], and seven with low-level resistance (R/S of 2.0 to 2.8). Seven populations were fluroxypyr-resistant; five with high-level resistance (R/S of 13.2 to 29.8) and two with low-level resistance (R/S of 3.8 to 4.0). Six populations were cross resistant to dicamba and fluroxypyr, four were resistant to dicamba only, and one was resistant to fluroxypyr only. These results indicate that kochia populations in Alberta are resistant to one or more synthetic auxin active ingredients. Further research is required to determine whether resistance to dicamba or fluroxypyr alone, and in combination, is conferred by one or more resistance mechanisms.

A Survey of Florida Panhandle Row Crop Producers on Weeds Problem and Management Practices. Pratap Devkota*[1], Ethan T. Carter[2], Rhoda T. Broughton[3]; [1]University of Florida, Jay, FL, [2]University of Florida, Marianna, FL, [3]University of Florida, Live Oak, FL (057)

In Florida Panhandle, cotton and peanut are the major row crops production systems. A survey was conducted to assess weed issues and weed management practices in these production systems. Paper survey forms were distributed at county extension meetings and 88 responses were collected. Conventional, strip-tilled, and no-till systems were adopted by 22, 58, and 20% of the respondents, respectively. Most of the growers reported Palmer amaranth (35%) and pigweed spp. (12%) as the most problematic weed. Other major weeds reported were tropical spiderwort (11%), sicklepod (12%), annual grasses (9%), and perennial weeds (21%). The response on herbicide program illustrated that burndown was implemented by 60; PRE by 48; EPOST plus residual by 49; EPOST by 41; LPOST by 27; and LPOST plus residual by 24 respondents. About 43% of the growers reported the presence of herbicide resistant weeds; 20% suspected herbicide resistant weeds; 18% reported not present; and 20% reported unknown about spread of herbicide resistant weeds in their production systems. Collectively, Palmer amaranth was listed as the major herbicide-resistant weed in this region. For herbicide resistant weed management, using PRE and POST herbicides, crop rotation, and hand weeding/hoeing were the major strategies. There was greater interest in herbicide programs (55 respondents) and less interest in mechanical (11 respondents), cover crops (18 respondents), and integrated programs (18 respondents) as weed management strategies. The response on adoption of dicamba and 2,4-D resistant crops were mixed, where 26% of respondents were not interested, 40% were moderately interested, 28% were highly interested, and 5% were only interested in seed trait but not in newer dicamba and 2,4-D herbicide formulations. The major concern for adoption of dicamba and 2,4-D resistant crops were indicated as issues with drift, cost of the technology, regulatory environment, and potential for volatility/off-target movement of these herbicides.

Guayule (*Parthenium argentatum*) Seedling Response to Carfentrazone-ethyl. Bryan C. Pastor*[1], Guangyauo Sam Wang[2], William B. McCloskey[1]; [1]University of Arizona, Tucson, AZ, [2]Bridgestone Americas, Inc, Eloy, AZ (058)

Guayule is a desert adapted plant from the Chihuahuan Desert in North America that produces natural rubber. Weed control is a significant barrier to commercial rubber production from guayule. Preliminary postemergence herbicide screening studies in transplanted guayule found that guayule had some tolerance to carfentrazone-ethyl (Aim® herbicide from FMC) and other protoporphyrinogen oxidase inhibitors. Studies were initiated in direct-seeded guayule to further characterize guayule seedling tolerance to carfentrazone at multiple locations in southern Arizona in 2018 and 2019 using randomized complete block designs with 4 to 6 replications. Carfentrazone was applied broadcast over-the-top of guayule plants at target growth stages, typically 2, 4, 6 and 8 to 10 leaf plants. The actual number of true leaves per plant were counted at the time of spraying in each experiment. Postemergence herbicide treatments were applied using a tractor-mounted boom sprayer equipped with TeeJet® TT-11002 nozzles operated at 279 kPa that delivered a spray volume of 180L/ha in medium droplets at 5 km/hr. This resulted in good coverage of sprayed plant surfaces. The carfentrazone rate ranged investigated included 8.7, 17.5, 26.2, 35.1, 52.7, and 70.1 g/ha (0.5, 1, 1.5, 2, 3, and 4 fl. oz./A); some studies only included a subset of these rates. All carfentrzone herbicide treatments included a non-ionic surfactant at 0.5% v/v. Tolerance was evaluated by comparing pre-spray stand counts with counts collected at various days after treatment (DAT). Additionally, plant height was directly measured and canopy ground cover was estimated from nadir photographs and pixel analysis of the resulting images. Carfentrazone injury symptoms were manifest as necrotic spots on guayule leaves and in the loss of leaves from seedlings. The degree of injury increased as the rate of carfentrazone increased but injury decreased with increasing plant size. The untreated controls showed that some stand loss is normal during establishment. Carfentrazone rates up to and including 35 g/ha (2 fl. oz./A) did not substantially increase stand loss even at the 2 and 4 true leave growth stages. At carfentrazone rates of 53 and 70 g/ha there was a slight increase in stand loss but commercially acceptable stands were still obtained (as judged from the lack of skips in the seed-line greater than 0.5 m). Carfentrazone injury resulted in a reduction of leaf area immediately after spraying. The 2 true-leaf guayule canopy ground cover (cm^2/m-row) 14 DAT with 17, 35, 53 and 70 g/ha was reduced 45, 78, 83 and 72%, respectively, compared to the untreated control in a 2018 experiment. Similarly, 3.6 true-leaf guayule canopy ground cover at 7 DAT with 17, 35, 53 and 70 g/ha was reduced 65, 82, 86 and 89%, respectively, compared to the untreated control in 2018. Similar results were observed in 2019. The guayule seedlings grew out of this injury. The heights of seedlings treated with 35 g/ha carfentrazone at the 2, 3.6, 5.6 and 10.4 true-leaf growth stages were only reduced by 13, 13, 8, and 8 percent at 55, 48, 41 and 29 DAT, respectively, in 2018. Similarly, the heights seedlings treated with 70 g/ha carfentrazone at the 2, 3.6, 5.6 and 10.4 true-leaf growth stages were reduced by 21, 24, 13, and 5 percent at 55, 48, 41 and 29 DAT, respectively in 2018. In 2019, plant heights were also reduced but to a lesser extent. In summary, guayule leaf area and plant height were reduced following treatment with carfentrazone but there was little stand loss and the plants grew out of the injury to establish commercially acceptable plant populations. These data indicate that Aim at rates of 17 to 35 g/ha (1 to 2 fl. oz./A of Aim®) can be used for broadleaf weed control in guayule provided growers are educated to expect some injury immediately after application.

Response of Common Louisiana Aquatic Weeds to Rice Herbicides. Benjamin M. McKnight*, Eric Webster, Samer Y. Rustom, Connor Webster, Bradley Greer, David C. Walker; Louisiana State University, Baton Rouge, LA (059)

Extended periods of inundation with flood irrigation water can select for the growth habit of aquatic weeds in Louisiana rice cropping systems rotated with crawfish (*Procambarus clarkii* Girard) production systems. A field study was conducted in the 2019 growing season to evaluate herbicide activity on troublesome aquatic weeds common to Louisiana rice/crawfish rotational systems at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana. Plot size was 1.5 m by 5.2 m and experimental design was a randomized complete block design with four replications. A 91-cm diameter galvanized metal ring was installed within each plot for herbicide treatment containment and to provide a defined area for transplanting aquatic weeds. A natural infestation of ducksalad [*Heteranthera limosa* (Sw.) Willd.], yellow nutsedge (*Cyperus esculentus*

L.), and alligatorweed [*Alternanthera philoxeroides* (Mart.) Grisb.] was present in the study area. Grassy arrowhead (*Sagittaria graminea* Michx.), pickerelweed (*Pontedaria cordata* L.), and ladysthumb (*Polygonum persicaria* L.) were transplanted into metal rings 3 weeks prior to treatment to allow for plant establishment. To minimize competition between rice plants and weeds no rice was planted in the study. Herbicide treatments consisted of seven herbicides labeled for use in rice production, applied alone or in mixture. All herbicide treatments included crop oil concentrate at 1% v v^{-1}. Herbicide application consisted of treating the entire plot with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} spray solution and a handheld spray boom with five flat-fan 110015 nozzles at 38-cm spacing. Visual injury ratings were recorded at 14, 28, 42, and 56 DAT. Plants were hand-harvested at the conclusion of the study, 56 DAT, and grouped by species for fresh weight biomass determination. The pre-packaged mixture of halosulfuron plus prosulfuron applied at 111 g ai ha^{-1} controlled grassy arrowhead, yellow nutsedge, pickerelweed and alligatorweed 96%, 96%, 97%, and 96% at 56 DAT, respectively. At 56 DAT, no biomass was present in containment rings for these species. Florpyrauxifen-benzyl controlled ladysthumb, pickerelweed, grassy arrowhead and ducksalad 55%, 90%, 96%, and 80% at 56 DAT, respectively, when applied at the label rate of 30 g ai ha^{-1}. Penoxsulam applied at 40 g ai ha^{-1} controlled pickerelweed, grassy arrowhead, yellow nutsedge, and alligatorweed 89%, 97%, 78%, and 93% at 56 DAT, respectively. Grassy arrowhead, yellow nutsedge, ladysthumb, and alligatorweed was controlled 97%, 84%, 79%, and 86%, respectively, following treatment with the pre-packaged mixture of penoxsulam plus triclopyr at 56 DAT. The results from this study indicate that several products labeled for use in rice production have activity on troublesome aquatic weeds in South Louisiana rice/crawfish rotations. These results will enhance current recommendations for growers developing weed management decisions in this rotational system.

Inzen™ Sorghum Weed Control Programs with Zest™ WDG Herbicide. David Saunders*[1], Joe Armstrong[2], Michael Lovelace[3], Jeffrey Krumm[4]; [1]Corteva Agriscience, Dallas Center, IA, [2]Corteva Agriscience, Indianapolis, IN, [3]Corteva Agriscience, Lubbock, TX, [4]Corteva Agriscience, Hastings, NE (060)

Inzen™ grain sorghum from Corteva Agriscience is a novel herbicide tolerance trait designed to provide producers with a new tool for postemergence grass control in grain sorghum. Five field trials were conducted in 2019 in the central and southern Great Plains regions to evaluate one- and two-pass herbicide programs in Inzen grain sorghum using nicosulfuron (Zest™ WDG, 75% active ingredient) for postemergence (POST) weed control. Treatments consisted of acetochlor + atrazine (2270 + 1120 g ai/ha) applied preemergence (PRE), acetochlor + atrazine PRE followed by (fb) nicosulfuron + atrazine (35 or 70 + 840 g ai) POST, acetochlor + atrazine + nicosulfuron (2270 + 1120 + 35 g ai) POST, and nicosulfuron + atrazine (35 or 70 + 840 g ai) POST. Across all trials, the two-pass program of acetochlor + atrazine PRE fb nicosulfuron + atrazine POST provided =88% control of key grass weeds including green foxtail (*Setaria viridis*), southwestern cupgrass (*Eriochloa gracilis*), and large crabgrass (*Digitaria sanguinalis*). Similarly, two-pass PRE fb POST programs also provided =95% of key broadleaf weeds in these trials, including Palmer amaranth (*Amaranthus palmeri*), kochia (*Kochia scoparia*), and Russian thistle (*Salsola iberica*). While the one-pass POST treatments also provided excellent control of these broadleaf weeds, sequential PRE fb POST programs provided the best and most consistent grass weed control and is the recommended best practice for Inzen grain sorghum. ™Trademarks of Dow AgroSciences, DuPont, or Pioneer and their affiliated companies or respective owners

Resicore® for PRE and POST Weed Control in Corn. David Saunders*[1], Joe Armstrong[2], Kevin Johnson[3]; [1]Corteva Agriscience, Dallas Center, IA, [2]Corteva Agriscience, Indianapolis, IN, [3]Corteva Agriscience, Lafayette, IN (061)

Corteva Agriscience has developed a broad spectrum weed control herbicide for use in corn. Resicore® herbicide is a premixture product containing the active ingredients acetochlor, mesotrione, and clopyralid in a novel suspoemulsion formulation for use in field corn, field seed corn, field silage corn, and yellow popcorn. With three effective modes-of-action, Resicore® provides broad spectrum control of most annual grasses and broadleaf weeds, with up to eight weeks or more of soil residual activity. It may also be applied in tank mixture with atrazine, glyphosate, and other corn herbicides, which provides flexibility to combine additional modes-of-action in a single application. Resicore® has a wide window of application, ranging from early preplant through postemergence when applied according to label directions. Results from research trials conducted across the U.S. corn belt have demonstrated excellent crop tolerance to Resicore® and broad spectrum preemergence and postemergence control of many key weeds, including several difficult-to-control species and herbicide-resistant biotypes such as giant ragweed (*Ambrosia trifida*), morningglory (*Ipomoea* spp.), and common waterhemp (*Amaranthus rudis*). For weeds such as Palmer amaranth (*Amaranthus palmeri*), the addition of 1 qt of atrazine adds the additional control needed to reach an excellent rating. Resicore® is an effective weed management tool and will play an important role in herbicide resistant weed control strategies and programs. ®™Trademarks of Dow AgroSciences, DuPont, or Pioneer and their affiliated companies or respective owners

Desert Cotton Responses to Low Doses of 2,4-D or Dicamba. William B. McCloskey*[1], Randy Norton[2], Bryan C. Pastor[1]; [1]University of Arizona, Tucson, AZ, [2]University of Arizona, Safford, AZ (062)

The development of cotton varieties resistant to 2,4-D or dicamba and the registration of new formulations of 2,4-D (Enlist One™) and dicamba (Engenia® and Xtendimax®) have increased concerns about the off-target movement of these auxin mimic herbicides. Growers of sensitive cotton injured by off-target drift of 2,4-D or dicamba typically want to know how much yield loss there will be at the end of the season. There is considerable variability in cotton's injury and yield responses to auxin herbicides that depends on many factors: 1) the herbicide, 2) the rate or dose, 3) cotton growth stage at the time of exposure, and 4) environmental conditions after exposure. Cotton injury caused by auxin herbicides depends on local conditions. Thus, experiments were conducted to study auxin herbicide symptom development and yield loss under irrigated desert conditions where cotton has ample time and resources to recover after injury. Experiments were conducted at the University of Arizona Red Rock and Maricopa Agricultural Centers to measure the response of cotton to simulated drift rates of dicamba and 2,4-D. The auxin herbicides were applied at different cotton growth stages; 4 leaf, first square (FS; i.e., first flower bud, usually around 7 to 8th node), first square+2 weeks (FS+2WK), first flower (FF) and first flower + 2 weeks (FF+2WK). Not all experiments included all growth stages. The 1X dicamba dose on dicamba-tolerant cotton is 0.5 lb. ae/A; dicamba (Clarity® in 2016, Xtendimax® in 2018 and 2019) was applied at 1X, 1/5X, 1/10X, 1/50X, 1/100X, and 1/500X doses; not all doses were applied in all experiments. The 1X 2,4-D dose on 2,4-D-tolerant cotton is 0.95 lb ae/A; 2,4-D (Enlist One™) was applied at 1/2X, 1/10X, 1/50X, 1/100X, 1/200X, and 1/500X. The herbicides were applied with a CO_2 pressurized backpack sprayer using a boom equipped with four TTI-110015 air induction nozzles on 20 inch centers calibrated to deliver about 15 GPA at 45 PSI. All herbicide treatments included a non-ionic surfactant at 0.25% v/v (Activator 90, Loveland Products). A factorial design with four replications was used arrange the 2-row plots that were 6.67 feet by 38 feet. There were several buffer rows of cotton between plots and a shield was used to limit downwind drift from the applications. Dicamba at 1X (0.5 lb ae/A) caused substantial cotton injury and delayed flowering and boll development but did not kill the plants in 2016 or 2018. In 2016, cotton lint yield was reduced 38, 55, 85 and 75% when sprayed with dicamba at 1X at the FS, FS+2WK, FF, and FF+2WK growth stages, respectively. Thus, the earlier the drift injury occurred, the more time cotton had to recover, flower and produce lint. In 2018, the plants were larger by the time they grew to the targeted growth stages because of early season drought and heat stress. Cotton lint yield in 2018 was reduced 67, 80, and 60% when sprayed with dicamba at the 1X rate at the FS, FF, and FF+2WK growth stages, respectively. In all three dicamba experiments (2016, 2018, 2019), dicamba rates of 1/50, 1/100, and 1/500 did reduce cotton lint yields. The 1/10X dicamba rate response was variable and reduced lint yield an averaged 12% and 19% in 2016 and 2018, respectively, while having no significant effect in 2019. In all experiments dicamba did not alter fiber quality, strength, or length. In contrast to dicamba at 0.5 lb. ae/A, 2,4-D at 1/2X (0.45 lb. ae/A) killed almost all of the cotton plants when sprayed in 2017 at the FS and FS+2WK growth stages and reduced lint yields when sprayed at the FF and FF+2WK growth stages 98 and 76%, respectively. At the 1/10X, 1/50X, 1/100X, 1/200X 2,4-D rates, lint yields decreased with increasing dose with the 1/10X rate causing a 90% yield reduction in 2017. Yields also increased as plant size at treatment increased; yields were greater at the FF+2WK growth stage. When the plants were larger and were treated later in the season in 2018, similar trends were observed as in 2017 but lint yields were reduced less than in 2017. For example, the 1/10X rate reduced yield 71, 82 and 68% at the FS, FF, and FF+2WK growth stages, respectively, and the 1/50X rate reduced yields 35, 47, 21% at the FS, FF, and FF+2WK growth stages, respectively. In 2019, Arizona experienced an unusually cool and wet spring at the start of the cotton season that delayed growth. Heat unit accumulation ran 3 to 4 weeks behind "normal". This weather pattern was combined with a severe thrips infestation at the Maricopa Agricultural Center that killed initial shoot meristems of plants resulted in a slim majority of the plants having two to three main stems rather than a single main shoot. As a consequence of the weather and thrips, the plants in the 2019 experiments were larger at the time 2,4-D was sprayed with the exception of the 4 leaf growth stage. The greatest dose of 2,4-D in 2019, 1/10X (0.095 lb. ae/A), caused significant visible injury and reduced lint yield 22, 92, 96, and 36% at the 4 LF, FS, FF, and FF+3WK, respectively. The lowest dose of 2,4-D, 1/500X, had little effect on lint yields. 2,4-D caused the greatest yield losses when applied at the FF followed by the FF+3WK growth stage. These applications occurred near the beginning and in the middle of the cotton bloom cycle and were especially damaging. Even after the plants partially recovered from the treatments and started producing flowers again, the flowers had damaged anthers that did not shed pollen for weeks after flower production resumed. Plants that were injured earlier in the season during vegetative growth had enough time to recover, resume flower and boll production and produce near normal yields. By the time the FF+3 week 2,4-D treatments were applied, some bolls were mature enough that seed and lint growth were able to continue and yields were not as severely reduced compared to the effects of the FF treatment. Despite the effect of 2,4-D on yield, there were no differences in lint fiber characteristics between any 2,4-D doses at any growth stage. In summary, dicamba off-target movement is not likely to cause large cotton lint yield losses except in the most extreme situations since cotton is more tolerant of dicamba than 2,4-D. Low doses of 2,4-D such as might occur as a result of off-target movement are most damaging to cotton at the beginning and during the first half of the bloom and fruiting cycle. Growers who suffer injury due to off-target movement of 2,4-D will need to closely monitor their crop for signs of regrowth. However, it is difficult to predict ultimate yield and growers will need to take the crop to yield to determine the extent of their loss. Plants injured in the early to middle phases of the reproductive cycle will suffer severe yield losses but may recover some later in the season, especially if grower inputs result in more mature bolls late in the season.

Field-scale Assessment of Dicamba Off-target Movement from Soybeans in Missouri. Reid Smeda*; University of Missouri, Columbia, MO (063)

Since 2017, reports of off-target dicamba damage to sensitive soybeans have been widespread. In 2019 near Millersburg, MO a large-scale field trial was carried out to assess the extent and source of potential dicamba damage to adjacent, sensitive soybeans. Twin 2.83 ha blocks were planted with dicamba-tolerant (DT) soybeans into wheat stubble in late June. Surrounding each block, dicamba-sensitive (DS) soybeans were planted in a 76 m border surrounding DT plants. In late July, glyphosate + dicamba + MON51817 + drift reduction agent was applied to DT soybeans using a commercial sprayer (10.7 m boom). Just prior to application, DS soybeans immediately adjacent to DT soybeans and in each ordinate direction were covered with plastic (3 x 15 m) to prevent particle drift. At 21 days after treatment (DAT), DS soybeans downwind from the initial application (wind NNE from 6.4 – 11.3 km/hr) exhibited up to 30% visual injury at 24 m from the DT soybean. For soybeans covered by the plastic tarps, visual injury ranged up to 5%. Multi-spectral drone and aircraft imagery (green, red, red-edge, and near-infrared; 550 nm, 670 nm, 717 nm, and 800 nm, respectively) were collected prior to dicamba application through soybean senescence during the 2019 study. Aerial imagery acquired 69 DAT (using enhanced green and red-edge bands) mapped symptomology in DS soybeans displaying initial dicamba injury. Furthermore, these mapped areas of symptomology were associated with soybeans exhibiting delayed senescence that was identified in aerial imagery captured 82 DAT. A yield monitor at harvest did not reveal a pattern for DS soybeans that could be attributed to dicamba injury. The majority of dicamba injury to DS soybeans reflected particle movement at the time of dicamba application; little to no secondary movement of dicamba was measured.

Impact of Cereal Rye Cover Crop Termination Timing on the Fate of Soil-applied Residual Herbicides in Wisconsin Corn-soybean Production Systems. Nicholas J. Arneson*, Kolby R. Grint, Nikola Arsenijevic, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (064)

Fall seeding cereal rye (*Secale cereal* L.) as a cover crop in a corn- (*Zea mays*) soybean (*Glycine max* L. merr) rotation is gaining popularity in Wisconsin and the Midwestern United States due to potential benefits such as reducing soil erosion and suppressing troublesome weeds. Cereal rye is often terminated chemically before cash crop planting to minimize competition with the crop; however, some farmers are terminating at or after planting to maximize rye biomass production. The use of residual PRE-emergence herbicides (PRE) are the foundation for effective weed control programs in corn and soybean production and are often tank mixed in a burndown application of cereal rye. There is concern that cereal rye intercepts and uptakes PRE herbicides which would limit their residual activity in the soil. In 2019, two separate experiments were conducted in Wisconsin to evaluate the impact of termination timing on the fate of residual PRE herbicides in corn and soybean. The first experiment was conducted in soybean near Arlington, WI in a RCBD (4 replicates) with a treatment factorial of 3 termination timings [8 days before planting (DBP), at planting (0 DAP), and 14 days after planting (DAP)] ? 2 herbicide programs [no PRE and sulfentrazone (150 g ai ha^{-1}) + S-metolachlor (1380 g ai ha^{-1})] for a total of 6 treatments. The second experiment was conducted in both corn and soybean (two separate studies) near Arlington and Lancaster, WI in a RCBD (4 replicates) with a treatment factorial of 5 soil management strategies [tillage, no till (NT), 14 DBP termination, 0 DAP termination, and 14 DAP termination] X 2 PRE herbicide programs [no PRE, mesotrione (179 g ai ha^{-1}) + S-metolachlor (1604 g ai ha^{-1}) + bicyclopyrone (45 g ai ha^{-1}) in corn, and sulfentrazone (202 g ai ha^{-1}) + metribuzin (303 g ai ha^{-1}) in soybean] for a total of 10 treatments. Termination of cereal rye at the different timings was achieved by applications of either glyphosate (1060 g ai ha^{-1}) or clethodim (2810 g ai ha^{-1}) + AMS (1430 g ha^{-1}) and all PRE treatments were applied 0 DAP. Soil samples (0-10 cm depth) were taken 25-29 DAP from selected treatments of each experiment for analytical analysis and a greenhouse bioassay evaluating residual control of Palmer amaranth (*Amaranthus palmeri*) and Cucumber (*Cucumis sativus*). Visual *A. palmeri* and *C. sativus* control and biomass was taken at 21 days after bioassay establishment. Cereal rye termination timing had no significant effect on either S-metolachlor or sulfentrazone concentration across experiments. Termination timing had inconsistent effects on *A. palmeri* and *C. sativus* biomass reduction in the greenhouse bioassays. The analytical results indicate that cereal rye termination timing did not impact the concentration of sulfentrazone and S-metalolachlor in soil in these experiments. More research is needed to evaluate species selection and value of greenhouse bioassays as indicators of herbicide fate in soil.Moreover, 2019 was an above average year for rainfall in Wisconsin which likely impacted these results. Further research is needed across diverse environments encompassing soils representative of corn-soybean production areas in the Midwest as well as with other residual herbicides to better understand the impact of cereal rye on residual herbicide fate.

Comparison of Layered Herbicide Residual Programs for Waterhemp Control in Wisconsin Soybean Production. Nicholas J. Arneson*, Ryan P. DeWerff, Daniel H. Smith, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (065)

Waterhemp (*Amaranthus tuberculatus* (Moq.) J.D. Sauer) is a troublesome weed common in corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr) production systems throughout Wisconsin and the Midwest United States. The rapid evolution and widespread distribution of resistance to multiple herbicide sites of action has made it difficult for producers to effectively control waterhemp with one POST-emergence herbicide (POST) application. As a result, both academic and industry scientists recommend a “layered” residual approach where a PRE-emergence herbicide (PRE) is followed by a timely residual POST herbicide application to provide season long control of waterhemp. In 2019, an experiment was conducted at two field sites (Brooklyn and Lancaster) in Wisconsin to evaluate the utility of layering residual herbicides for waterhemp control. The experiment was conducted in a RCBD (4 replicates) comparing ten herbicide treatments. Herbicide treatments consisted of PRE only (metribuzin, 227 g ai ha^{-1} + sulfentrazone, 151 g ai ha^{-1}), PRE followed by (fb) glufosinate (656 g ai ha^{-1}) alone, and PRE fb a tank mix of glufosinate (656 g ai ha^{-1}) + 8 different residual herbicide combinations [imazethapyr (70 g ai ha^{-1}), fomesafen (316 g ai ha^{-1}), acetochlor (1261 g ai ha^{-1}), S-metolachlor (1606 g ai ha^{-1}), dimethenamid-P (525 g ai ha^{-1}), pyroxasulfone, (89 g ai ha^{-1}), fomesafen (320 g ai ha^{-1}) + S-metolachlor (1460 g ai ha^{-1}), and fomesafen (276 g ai ha^{-1}) + acetochlor (1235 g ai ha^{-1})]. All POST applications were delivered at 140 L ha^{-1} and included 2242 g ha^{-1} of AMS. PRE applications were made 3 days after soybean planting (DAP) while POST applications were made 27-34 DAP at V2-V4 soybean growth stages. Visual evaluation of percent waterhemp control was measured at 14 and 24-33 days after the POST treatment (DAT). Soybean grain yield was measured using an Almaco plot combine at the Brooklyn location only. At Brooklyn, all PRE fb POST treatments resulted in = 90% waterhemp control at 14 DAT while only the PRE fb POST treatments that included fomesafen resulted in = 90% at 33 DAT. At Lancaster, all PRE fb POST treatments resulted in = 90% waterhemp control for both 14 and 24 DAT ratings. At Brooklyn, the PRE fb POST treatments resulted in a 1501-1983 kg ha^{-1} increase in soybean grain yield compared to the PRE only treatment ($P<0.001$). The value of the layered approach was more pronounced at Brooklyn where waterhemp pressure was greater than at Lancaster; however, further research is necessary to determine if layering residuals provides improved waterhemp control in fields with lower waterhemp density. This research will be replicated in 2020 growing season at these locations.

Potential for Gibberellic Acid as a Weed Seedbank Management Tool in Eastern Washington Dryland Systems. Rachel J. Zuger*, Amber L. Hauvermale, Ian Burke; Washington State University, Pullman, WA (066)

Weed seedbank management is an important component of integrated pest management. Persistence of weed seedbanks remain one of the most intractable problems facing weed managers. Annual invasive grasses such as downy brome and Italian ryegrass are problematic to Eastern Washington dryland wheat production typically persist in integrated cropping systems because of a large unmanageable seedbank. An alternative to tillage for weed seedbank management could be stimulating germination by applying gibberellic acid (GA) to the soil surface to break seed dormancy. The transition of a seed from dormant to germinating is controlled by growth regulators, GA and abscisic acid (ABA), as well as external environmental cues (light, moisture, temperature). Study objectives were 1) evaluate GA for simulation of downy brome and Italian ryegrass germination in a field setting; and 2) determine if increased herbicide efficacy could be achieved with the addition of GA_3 to preemergence (PRE) herbicides. For Objective 1, three downy brome and two Italian ryegrass germination trials were conducted in 2018 and 2019. In 2018, two downy brome trails were conducted in Anatone, WA (BROTE 1) and in Central Ferry, WA (BROTE 2), and one Italian ryegrass trial was performed in Pullman, WA (LOLMU 1). One downy brome trail in Davenport, WA (BROTE 3) and one Italian ryegrass trial in Pullman, WA (LOLMU 2) were conducted in 2019. Treatments included 0, 1.4, 14, 28, and 1400 g GA_3 ha^{-1} (RyzUp Smartgrass, Valent BioSciences Corporation). Italian ryegrass studies had an additional treatment of 28 g GA_3 ha^{-1} with 89 g pyroxasulfone ha^{-1}. Downy brome germination in 2018 was not significantly increased by any GA_3 treatment, although for BROTE 1 GA_3 applied at 14 g ai ha^{-1} resulted in the greatest downy brome counts of 2750 plants m^{-2} and BROTE 2 had increasing plants m^{-2} as GA_3 increased. In 2019, BROTE 3 did not receive adequate rainfall 2 weeks after GA_3 application resulting in little to no plants m^{-2}. Similar results were observed with downy brome biomass for 2018 and 2019. The LOLMU 1 trial in 2018 resulted in an increase in Italian ryegrass counts and biomass as GA_3 concentration increased. In 2019, trial LOLMU 2 resulted in similar counts and biomass among treatments. For Objective 2, GA_3 (12 or 14 g ai ha^{-1}) was combined with either pyroxasulfone (90 g ai ha^{-1}), sulfosulfuron (34.7 g ai ha^{-1}), pyroxasulfone (90 g ai ha^{-1}) with sulfosulfuron (53 g ai ha^{-1}), or pyroxasulfone (89 g ai ha^{-1}) with flumioxazin (70 g ai ha^{-1}) in either winter wheat, spring wheat, or fallow. The combination of GA_3 with a PRE herbicide did not improve weed control (downy brome or Italian ryegrass) compared to the PRE herbicide alone. Crop yields were also not affected by the additional of GA_3 to the PRE herbicides. Environmental factors such as precipitation, soil temperature, and air temperature play an important role in the effectiveness of GA_3 in a field setting with precipitation being the biggest factor. We estimate rainfall events 2 weeks after GA_3 applications need to total 1.80 cm or greater precipitation. Soil temperatures at time of application need to be around 10°C for downy brome with decreasing temperatures after application, while for Italian ryegrass soil temperatures can be 6°C at application with increasing temperatures afterwards. Based on these results, more research needs to be completed to understand the environmental conditions required for GA_3 activity. Stimulating germination of downy brome and Italian ryegrass with GA_3 could potentially be an effective tool for weed seedbank management.

Impact of Cover Crop Mixtures and Climate Conditions on Weed Communities. Mary E. DuPre[1], Maryse Bourgault[2], Darin Boss[2], Chris Larson[1], Fabian D. Menalled[1], Tim Seipel*[1]; [1]Montana State University, Bozeman, MT, [2]Montana State University -Northern Ag Research Center, Havre, MT (067)

Abstract not available

Potential Yield Loss from Uncontrolled Weeds in Rice in North America. Sandeep S. Rana*[1], Wesley Everman[2], Anita Dille[3], Peter H. Sikkema[4], Michael L. Flessner[5], Ian Burke[6], Mark VanGessel[7]; [1]Bayer Crop Science, Galena, MD, [2]North Carolina State University, Raleigh, NC, [3]Kansas State University, Manhattan, KS, [4]University of Guelph, Ridgetown, ON, Canada, [5]Virginia Tech, Blacksburg, VA, [6]Washington State University, Pullman, WA, [7]University of Delaware, Georgetown, DE (068)

Although the USA accounts for only 2% global rice production, it ranks as the fifth- or sixth-largest rice exporter with approximately 6% global exports. Weed interference continues to present a major threat to USA rice production and results in significant crop losses. In an effort to report rice yield losses due to weeds, the Weed Science Society of America (WSSA) Weed Loss Committee requested researchers and/or extension weed specialists across the USA rice-growing regions to provide comparative yield loss data from up to 10 individual replicated studies per year ranging from 2007 to 2019. The yield loss estimates were determined by comparing rice yields

between nontreated, weedy controls and treatments with =95% weed control averaged across studies within a year, and then averaged over the total number of years for each state. The percent yield loss values were then used to determine rice yield loss based on average rice yield for the region and year-specific commodity prices as summarized by USDA-NASS (2007 – 2019 average). Rice yield losses averaged across years were 85, 53, 74, and 67% for Arkansas, California, Mississippi, Missouri, respectively. Averaged across years and growing regions, uncontrolled weeds reduced rice yields by 70%. With an average yield of 185 kg ha^{-1} (65 bu $acre^{-1}$) and price of $297.87 metric ton^{-1} ($6.08 bu^{-1}) (USDA-NASS, 2007- 2019 average), this yield loss corresponds to 1.3 million metric tons (68 million bu) loss in production and $0.4 billion loss in value for the USA rice.

Potential Yield Loss from Uncontrolled Weeds in Cotton in North America. Sandeep S. Rana*[1], Wesley Everman[2], Anita Dille[3], Peter H. Sikkema[4], Michael L. Flessner[5], Ian Burke[6], Mark VanGessel[7]; [1]Bayer Crop Science, Galena, MD, [2]North Carolina State University, Raleigh, NC, [3]Kansas State University, Manhattan, KS, [4]University of Guelph, Ridgetown, ON, Canada, [5]Virginia Tech, Blacksburg, VA, [6]Washington State University, Pullman, WA, [7]University of Delaware, Georgetown, DE (069)

The USA is ranked third in global cotton production and serves as the key producer providing a third of the world's cotton exports. Cotton yields continue to be threatened by weed interference resulting in major crop losses. The objective of the Weed Science Society of America (WSSA) Weed Loss Committee is to report cotton yield and value losses due to uncontrolled weeds. To achieve this objective, the committee requested researchers and/or extension weed specialists across the cotton belt in the USA to report average lint yield of weedy, nontreated control plots vs treatments that controlled weeds =95% for up to 10 replicatied studies per year for the period of 2007 to 2019. Percent yield loss was then determined for each study first averaged within a year and then across years for each state, based on average cotton yields summarized by USDA-NASS (2007 – 2019 average). Cotton yield losses ranged from 49 to 82% for the states reported here: Arkansas, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, and Texas. Averaged across years and growing regions, weed interference reduced cotton yields by 71%. With an average lint yield of 1029 kg ha^{-1} (918 lb $acre^{-1}$) and price of $1587.33 metric ton^{-1} ($0.72 lb^{-1}) (USDA-NASS, 2007- 2019 average), this yield loss corresponds to 0.3 million metric tons (0.5 billion lb) loss in production and $0.4 billion loss in value for the USA cotton.

Evaluation of Weed Control Programs in Furrow Irrigated Rice (*Oryza sativa*). Leah M. Collie*[1], Tom Barber[1], Thomas R. Butts[1], Ryan C. Doherty[2], Zachary T. Hill[3], Aaron Ross[4]; [1]University of Arkansas System Division of Agriculture, Lonoke, AR, [2]University of Arkansas Division of Agriculture Research & Extension, Monticello, AR, [3]University of Arkansas Cooperative Extension Service, Monticello, AR, [4]University of Arkansas, Lonoke, AR (070)

With the widespread increase in furrow-irrigated rice acres, weed control programs and their effectiveness in this system have come under question. The purpose of this research was to determine the most effective herbicide program for season-long weed control in furrow-irrigated rice. Experiments were conducted from 2017-2019 at Marianna, Arkansas on a Calloway silt loam soil in a randomized complete block design. Individual plots were 3.7 meters wide and 9 meters in length. Rice cultivar XP745 CL was planted at 28 kg ha^{-1}. Several herbicide programs were evaluated, all of which contained clomazone PRE alone and in combination with other herbicide modes of action, followed by two POST applications of various herbicide combinations. All herbicide applications were made with a spray volume of 112 L ha^{-1} and visual ratings for weed control were taken at 28 days after planting (DAP) and 14 days after the final late post application (LPOST). Palmer amaranth control was highest 28 DAP when saflufenacil 0.05 kg ai ha^{-1} was applied with clomazone PRE. Palmer amaranth control POST was only achieved 14 days after LPOST with multiple applications or combinations of florpyrauxifen-benzyl applied at 0.0109 - 0.0146 kg ai ha^{-1} or with a tankmix combination of propanil 3.37 kg ai ha^{-1} plus triclopyr 0.21 kg ai ha^{-1}. Results indicate, two applications of one of the previous two herbicide mixtures will be needed for season-long Palmer amaranth control in furrow-irrigated rice. Barnyardgrass *(Echinochloa crus-galli* L.*)* control was similar to management in a flooded rice environment, however, residuals become more important in a furrow-irrigated rice system. Applications of imazethapyr early POST followed by either cyhalofop, fenoxaprop or bispyribac LPOST provided the highest control of barnyardgrass by 14 days LPOST. If POST applications were not made timely then barnyardgrass control was significantly reduced. Goosegrass *(Eleusine indica* L.*)* control was highest (87%) when cyhalofop was applied in a program LPOST. The weed spectrum appeared to shift more towards broadleaves and difficult to control grasses in the furrow-irrigated rice system. Producers should budget at least one extra herbicide application in furrow-irrigated rice production for difficult to control weeds and increased weed germination late season in absence of the flood. Additionally, multiple residual herbicide applications should be overlapped to prevent continuous flushes of grass weed species.

Cotton and Soybean Response to Selected Drift Rates of Imazapyr and Metsulfuron. Michael W. Marshall*; Clemson University Edisto Research & Education Center, Blackville, SC (071)

In South Carolina, timber produced from forestland is an important agricultural industry. After harvest, the land is prepared for the new crop of trees. Trees and shrubs that are left after harvest are typically undesirable to carry forward in the new crop of trees. Several herbicide options are available to control these undesirable trees, woody shrubs, and other herbaceous plants that may compete with the new crop of tree seedlings. The summer following harvest (prior to winter planting) is typically the most appropriate time to control these plants. Helicopters equipped with a spray boom are used to aerially apply these herbicides. The potential drift from these aerial applications have the potential to injure cotton and soybeans. The severity of the crop injury will depend on the growth stage and the amount of drift received. Therefore, research is needed on the effect of drift rates of imazapyr and metsulfuron on early season cotton and soybean growth and development and yield. Field experiments were conducted at the Edisto Research and Education Center in 2019. Cotton variety Phytogen '480 W3FE' and Asgrow '74X8'was planted on May 16, 2019 and June 19, 2019, respectively. The drift herbicide treatments were 1/10 X and 1/100 X of the normal use rates (X) of imazapyr at 3.36 kg ha^{-1} and metsulfuron at 0.14 kg ha^{-1}. An untreated check was included for comparison. Percent cotton and soybean visual injury and heights were collected 7 and 14 days after treatment (DAT). Cotton was harvested on November 7, 2019 and soybean was harvested on November 21, 2019. Percent crop injury, height, and yield were analyzed using ANOVA and means separated at the P = 0.05 level. Metsulfuron at the 1/10X drift rate severely injured soybean at 7 DAT (77 and 71%, respectively). The injury increased to 98 and 88% at 28 DAT, respectively. In contrast, soybean injury was much lower (22 and 27% at 7 and 28 DAT, respectively) in the 1/10X imazapyr rate. Soybean heights were also reduced 80 and 69% in the 1/10X and 1/100X metsulfuron. Soybean yield was reduced in 1/10X and 1/100X metsulfuron compared to the untreated check (25 and 1220 kg ha^{-1}, respectively). In the vegetative growth stage, metsulfuron at the 1/10X drift rate severely injured cotton at 14 DAT (>80%). AT 7DAT, cotton injury ranged from was 11 to 22% across the treatments. However, cotton injury increased significantly to 83, 83, and 55% for the imazapyr at 1/10X, metsulfuron at 1/10X and 1/100X treatments at 14DAT. Cotton heights were significantly reduced by the 1/10X imazapyr, the 1/10X metsulfuron, and the 1/100X metsulfuron treatments compared to the untreated check. Seed cotton yields were significantly reduced by the 1/10X of imazapyr and metsulfuron and 1/100X metsulfuron treatments. In conclusion, cotton was the most sensitive to the 1/10X drift rates of imazapyr and metsulfuron. Soybean was highly sensitive to metsulfuron (at both the 1/10X and 1/100X drift rates). Based on the results from this study, growers can expect significant yield losses when an application of imazapyr (cotton only) or metsulfuron (in both cotton and soybean) drifts onto their crop.

Large-Scale Evaluation of 2,4-D Off-Target Movement in Wisconsin Soybeans. Rodrigo Werle*, Nicholas J. Arneson, Maxwel Coura Oliveira, Ryan P. DeWerff; University of Wisconsin-Madison, Madison, WI (072)

Enlist E3 technology allows for over-the-top applications of labeled glyphosate, glufosinate and 2,4-D herbicides. Growers' adoption of Enlist E3 soybean is expected to be high across the Midwest due to widespread occurrence of herbicide-resistant weeds. Large-scale applications of 2,4-D raise concerns and warrants investigations regarding its potential off-target movement (OTM). A large-scale drift research experiment was established near Sun Prairie, Wisconsin in 2019, whereas Enlist soybeans were planted in a 3 ha block, surrounded by 11 ha of non-Enlist soybeans. Enlist Duo (2,4-D choline + glyphosate) application was performed following label requirements on August 2 (24 C temperature). Wind speed was 5 kph at the onset of the application but dropped below this minimum requirement during application. At 21 days after treatment (DAT), non-Enlist soybean injury was visually assessed (0 to 100% injury). Moreover, paper filters were placed at seven distances up to 10 m from Enlist soybean block on the East (upwind) and on three downwind directions (northwest, west-central and northeast). Paper filters were retrieved shortly after application, 2,4-D concentration analyzed by the Mississippi State Chemical Laboratory, and deposition (?g cm^{-2}) estimated via a three-parameter log-logistic model. Neighboring sensitive vegetation (tomato gardens and vineyard) combined with adverse climatic conditions in July postponed the Enlist Duo application to August (R2 soybean stage). Results showed less than 5% injury of non-Enlist soybean (considered a compatible crop) in the downwind directions and no observable injury in the upwind direction. The average in swath 2,4-D deposition was 9966 ?g cm^{-2}, whereas an average of 9,360 ?g cm^{-2} was detected adjacent to the application block. Deposition of 2,4-D decreased 99% from 0 to 0.3 m from the Enlist block, reaching nearly 0 ?g cm^{-2} at 10 m. The low detection of 2,4-D at > 0.3 m from Enlist indicates the importance of following label requirements to reduce the chances of unintended OTM of 2,4-D via particle drift. Also, the late application timing under low wind speed combined with the lower inherit sensitivity of soybeans to 2,4-D likely minimized the risks of 2,4-D injury to non-Enlist soybeans. Further studies are needed to investigate potential unintended OTM of 2,4-D applied at vegetative soybean stages under different adverse weather conditions

Aerial Imagery as a Potential Tool to Evaluate Dicamba Off-Target Movement in Soybeans. Rodrigo Werle*[1], Randy Pearson[2], Josh Pristolas[2], Maxwel Coura Oliveira[1], Ryan Rector[3]; [1]University of Wisconsin-Madison, Madison, WI, [2]Southern Illinois University Edwardsville, Edwardsville, IL, [3]Bayer Crop Science, St Louis, MO (073)

The widespread occurrence of herbicide-resistant broadleaf weeds has led to a rapid adoption of the novel dicamba-tolerant soybean trait (Xtend technology; DT soybean) and POST-emergence application of registered dicamba products. Non-DT soybean varieties are extremely sensitive to dicamba and symptomology caused by dicamba off-target movement (OTM) has become a major concern regarding this technology. A large-scale OTM trial was conducted at UW-Madison Arlington Agricultural Research Station, near Arlington, Wisconsin in 2019. DT soybean was planted in a 3 ha block surrounded by 9 ha of non-DT soybean. Xtendimax, Roundup PowerMax, Intact and MON-51817 were sprayed on July 14 following label requirements. Dicamba symptomology in non-DT soybean 3 weeks after application followed wind direction during and after application (0-48 hours). Soybean dicamba symptomology decreased as distance from treated area increased whereas minor to no symptomology was observed after 35 m downwind from the treated area. Multispectral drone and aircraft imagery (green, red, red-edge, and near-infrared; 550 nm, 670 nm, 717 nm, and 800 nm, respectively) were collected from pre-application through crop senescence. Symptomology was accurately mapped at 4-5 weeks after application in non-DT soybean with digital enhancement methods of the green and red-edge bands, but could be initially detected at 7 days after application. Moreover, at 8 weeks after application, image enhancement of the red-edge band still accurately identified downwind dicamba symptomology in the non-DT soybean. Similar results were obtained using an ASD FieldSpec Handheld 2 VNIR Spectroradiometer (325-1075 nm). These results highlight the potential of using aerial imagery to document dicamba symptomology to non-DT soybean.

Weedy Rice (*Oryza sativa* f. *spontaneae*) Emergence and Growth Under Variable Irrigation Practices. Whitney Brim-DeForest*[1], Luis Espino[2]; [1]University of California Division of Agriculture and Natural Resources, Yuba City, CA, [2]University of California Division of Agriculture and Natural Resources, Oroville, CA (074)

Weedy rice (*Oryza sativa* f. *spontanea*) is a relatively new species in California rice. Five phenotypically and genetically distinct biotypes were identified in 2016, with differing characteristics, in terms of dormancy and early growth. However, all experiments to date have been carried out in the greenhouse. A field experiment was started in 2019 comparing weedy rice emergence under two irrigation regimens. Treatment 1, Continuous Flood (CF), was broadcast-seeded into a flooded field (10 cm deep). The plots were maintained with a 10-cm flood up to approximately 1 month before harvest. Treatment 2, Stale Seedbed (SS) was lightly tilled in the spring, followed by a flush of water to allow weedy rice germination. Approximately 1 week after the initial flush, the field was flushed again. About 2 weeks after the initial flush, the field was flooded to 10 cm, and rice was seeded into the flooded field. Prior to the start of this experiment, weedy rice types 1, 2, 3, and 5 were seeded into the plots (in 2018, and again in the spring of 2019). Three plots of each weedy rice type were placed in each irrigation system (CF and SS). From the start of irrigation water application in the field, in 2019, weedy rice counts were taken daily, from three rings (929 cm^2 each) placed in each plot. Temperature (?C) was logged hourly in each plot, and volumetric water content (cm^3 cm^{-3}) was also logged in the flushed plots. The experiment will be repeated in 2020 and 2021, so results are still preliminary. All weedy rice biotypes emerged under both flooded and flushed conditions, with a larger percentage of all types emerging under flushed conditions. Emergence timing (in days), was similar under all conditions with all weedy rice types.

Evaluation of Benzobicyclon and ALS-inhibiting Herbicide Combinations for Control of Northern Jointvetch (*Aeschynomene virginica*) and Hemp Sesbania (*Sesbania herbacea*) in Drill Seeded Rice (*Oryza sativa*). Nathan Pearrow*[1], Craigs Sandoski[2], Brad M. Davis[3], Thomas R. Butts[3]; [1]University of Arkansas, Newport, AR, [2]Gowan, Collierville, TN, [3]University of Arkansas System Division of Agriculture, Lonoke, AR (075)

Evaluation of benzobicyclon and ALS-inhibiting herbicide combinations for control of Northern jointvetch (*Aeschynomene virginica*) and Hemp Sesbania (*Sesbania herbacea*) in Drill Seeded Rice (*Oryza sativa*). N. Pearrow, T. R. Butts, B. Davis, and C. Sandoski Hemp sesbania (*Sesbania herbacea*) and northern jointvetch (*Aeschynomene virginica*) are among the top ten problematic rice weeds in Arkansas according to a crop consultant survey. Both weeds produce “black seed” that is difficult to separate from rice during harvest, leading to weed seed in grain samples at the mill. The objective of this research was to determine a viable herbicide option to control hemp sesbania and northern jointvetch in a post-flood salvage situation. Two studies were conducted in the summer of 2019 at the University of Arkansas at Pine Bluff Small Farm Outreach Center near Lonoke, AR. The first study evaluated efficacy of several ALS-inhibiting herbicides [halosulfuron (Permit), halosulfuron + thifensulfuron (Permit Plus), and halosulfuron + prosulfuron (Gambit)] applied alone at multiple rates on hemp sesbania and northern jointvetch. Treatments consisted of halosulfuron at 17, 35, 53, and 70 g $aiha^{-1}$, halosulfuron + thifensulfuron at 18 + 2 and 36 + 4 g $aiha^{-1}$, respectively, and halosulfuron + prosulfuron at 18 + 11, 36 + 22, 54 + 33, and 72 + 44 g $aiha^{-1}$, respectively. The second study evaluated tank-mixture options of ALS-inhibiting herbicides [halosulfuron (Permit) and halosulfuron + prosulfuron (Gambit)] at multiple rates with benzobicyclon for the control of hemp sesbania and northern jointvetch. Treatments consisted of benzobicyclon at 247 g $aiha^{-1}$ applied alone and in combination with halosulfuron at 53 and 70 g ai ha^{-1}, and in combination with halosulfuron + prosulfuron at 18 + 11, 27 + 17, and 36 + 22g ai ha^{-1}, respectively. Both experimental designs were randomized complete block designs with four replications in the first study and three replications in the second study. Treatments were applied post-flood with a CO_2 backpack sprayer equipped with DG 110015 tips calibrated to deliver 94 L ha^{-1}. Visual weed control ratings were taken weekly and were estimated using a scale of 0% to 100% where: 0% is no control and 100% is complete plant death. Data were subjected to analysis of variance and means were separated using Fisher's protected least significant difference test at a 5% level of significance. In the first study, all treatments provided 98% or greater control of both weedspecies at 3 weeks after treatment (WAT). At pre-harvest, all treatments still provided excellent control of greater than 94%. In the second study, all treatments provided 85% or greater control of hemp sesbania and northern jointvetch at 4 WAT with the exception of benzobicyclon alone providing less than 10% control of both weed species. At pre-harvest, hemp sesbania control remained above 85% for all treatments excluding the benzobicyclon alone treatment which was less than 30%. Northern jointvetch control with benzobicyclon plus halosulfuron at 53 and 70 g ai ha^{-1}, and benzobicyclon plus halosulfuron + prosulfuron at 36 + 22g ai ha^{-1}, respectively, provided greater than 80% control while the remainder of the treatments provided less than 70% control. Benzobicyclon alone showed no control of northern jointvetch at pre-harvest. Weed size and timing of application are critical in the control of these problematic rice weeds in Arkansas. Any of the three ALS-inhibiting herbicides evaluated in this research applied at label rates either alone or in combination with benzobicyclon can control these problematic weeds as a salvage option in flooded rice.

A Multi-State Screen of Field Populations of Horseweed (*Conyza canadensis*) to Applications of Dicamba and Glufosinate. Nicholas R. Steppig*[1], Julie M. Young[2], Kevin W. Bradley[3], Jason K. Norsworthy[4], Karla L. Gage[5], Aaron Hager[6], Greg R. Kruger[7], Mark Loux[8], Larry Steckel[9], Bryan G. Young[2]; [1]Purdue University, Lafayette, IN, [2]Purdue University, Brookston, IN, [3]University of Missouri, Columbia, MO, [4]University of Arkansas, Fayetteville, AR, [5]Southern Illinois University Carbondale, Carbondale, IL, [6]University of Illinois, Urbana, IL, [7]University of Nebraska-Lincoln, North Platte, NE, [8]Ohio State University, Columbus, OH, [9]University of Tennessee, Jackson, TN (076)

The introduction of soybean varieties with tolerance to dicamba and/or glufosinate has led to increased post-emergence (POST) applications of both herbicides across the United States in recent years. In the past, heavy reliance on POST applications of herbicides, such as glyphosate, led to the selection of resistant biotypes of several weed species, including horseweed (*Conyza canadensis*). In an attempt to detect early-stage resistance to dicamba and glufosinate in horseweed, 96 populations were collected from soybean fields in Illinois, Indiana, Missouri, Nebraska, Ohio, and Tennessee, prior to crop harvest in 2018. Inflorescences from 20 individual plants within each population were combined to create a composite sample for resistance screening under greenhouse conditions in 2019. Applications of dicamba (140 or 560 g ae ha^{-1}) or glufosinate (164 or 656 g ai ha^{-1}) were made, corresponding to 1/4X and 1X field use rates for each herbicide, once rosettes from composite samples reached 5cm in diameter. An application of the 1X rate of glufosinate provided complete control of all populations evaluated at 21 days after applications (DAA), indicating that POST applications of current field use rates are efficacious on theses populations. When averaged across populations, applications of the 1X rate of dicamba resulted in average horseweed mortality (= 95% visual control) of 99% at 21 days after application (DAA). However, several populations were identified where mortality was <90% following applications of the 1X rate of dicamba, indicating that individual mother plants within these population may be expressing an altered phenotypic response (i.e. less sensitive) to the herbicide. As a result, discriminating doses of dicamba will be applied to progeny of individual mother plants from these populations of interest, and subsequent full rate titrations will be conducted, as necessary, to identify individual plants with reduced sensitivity to dicamba

How to Avoid Glyphosate Injury in Glyphosate-Resistant Alfalfa. Earl Creech*[1], Chet Loveland[1], Matt Yost[1], Corey V. Ransom[1], Dan Putnam[2]; [1]Utah State University, Logan, UT, [2]University of California, Davis, Davis, CA (077)

Considerable research before and after the commercial release of glyphosate-resistant (GR) alfalfa demonstrated essentially no perceptible crop injury. However, in 2014, Steve Orloff (University of California) received reports from several northern California growers of apparent injury to GR alfalfa following an application of glyphosate. To our knowledge, this was the first report of a significant crop injury problem related to GR alfalfa. Over the next 5 years, similar injury was widely observed in production fields and in dozens of replicated research plots in California and Utah. These trials show that crop injury can be avoided by applying glyphosate to GR alfalfa that is no greater than 2 inches tall. When a low rate of glyphosate was used (22 oz/ac of Roundup PowerMax), application height can be extended to 4 inches. Our experience has shown that weed control at the 2 inch alfalfa height is usually excellent. If a grower is concerned about weeds that emerge after glyphosate application, a soil residual herbicide should be tank-mixed with glyphosate to extend control until canopy closure.

Control of Palmer Amaranth (*Amaranthus palmeri*) with Glufosinate and S-metolachlor in Cotton Production Systems. William J. Rutland*[1], Darrin M. Dodds[2], Jacob P. McNeal[2], John J. Williams[2], Bradley J. Norris[2], Steven D. Hall[1]; [1]Mississippi State University, Starkville, MS, [2]Mississippi State University, Mississippi State, MS (078)

An experiment was conducted in Dundee, MS, to evaluate weed control programs to control Palmer amaranth (*Amaranthus palmeri*) in XtendFlex® cotton production systems. The location for this experiment (Dundee, MS) was selected due to the presence of a natural infestation of glyphosate-resistant Palmer amaranth. Four-row plots were planted to DP 1646 B2XF on 20 June 2019 at a population of 111,197 seed ha^{-1}. At this time, plots received a preemergence application of pendimethalin at 0.37 kg a.i. ha^{-1}. The specific objective of this field study was to compare Palmer amaranth efficacy with pre-mix vs. tank-mix applications of glufosinate, s-metolachlor, and acetochlor. Applications were initiated when Palmer amaranth reached an average height of 10 cm and were made with a CO_2 powered backpack sprayer while traveling at a speed of 4.8 km h^{-1}. Applications included a pre-mixed formulation of glufosinate + s-metolachlor (Intermoc®) applied at 1.1 kg a.i. ha^{-1}, vs. tank-mix applications of glufosinate (Interline®) applied at 0.66 kg a.i. ha^{-1}) + s-metolachlor (Moccasin II Plus®) applied at 1.07 kg a.i. ha^{-1}, and glufosinate (Interline®) applied 0.66 kg a.i. ha^{-1} + acetochlor (Warrant®) applied at 1.06 g a.i. ha^{-1}. Data collection included visual Palmer amaranth control at 7, 14, 21, 28, and 35 days after treatment (DAT). The center two rows of each plot were mechanically harvested with a spindle picker modified for research purposes. Data were analyzed in SAS v9.4 utilizing a PROC GLIMMIX procedure. Data were subjected to analyses of variance and means were separated using Fisher's Protected LSD at an a level of 0.05. At 21 DAT, palmer amaranth varied due to treatment ($p < .001$). All treatments resulted in greater palmer amaranth control than the non-treated control. Additionally, a tank-mix of glufosinate + acetochlor resulted in 11% greater Palmer amaranth control than the premix formulation of glufosinate + s-metolachlor and the tank-mix application of glufosinate + s-metolachlor. At 7, 14, 28, and 35 DAT, Palmer amaranth control varied due to treatment ($p < .001$). All herbicide treatments resulted in greater Palmer amaranth control than the non-treated control; however, Palmer amaranth control did not vary due to herbicide treatments. These data indicate that pre-mix formulations of glufosinate and metolachlor have utility for controlling Palmer amaranth in cotton production systems.

The Effect of Multiple Exposure of Auxin Herbicide on Soybeans. Beau J. Varner*[1], Kevin W. Bradley[2], Aaron Hager[3], Karla L. Gage[4], Daniel B. Reynolds[1], Jason K. Norsworthy[5], Larry Steckel[6], Bryan G. Young[7]; [1]Mississippi State University, Mississippi State, MS, [2]University of Missouri, Columbia, MO, [3]University of Illinois, Urbana, IL, [4]Southern Illinois University Carbondale, Carbondale, IL, [5]University of Arkansas, Fayetteville, AR, [6]University of Tennessee, Jackson, TN, [7]Purdue University, Brookston, IN (079)

Abstract not available

Low Tunnel Evaluation of Dicamba Premixes. Graham Oakley*[1], A Stanley Culpepper[2], Daniel B. Reynolds[1], Reid Smeda[3], Christy Sprague[4], Rodrigo Werle[5]; [1]Mississippi State University, Mississippi State, MS, [2]University of Georgia, Tifton, GA, [3]University of Missouri, Columbia, MO, [4]Michigan State University, East Lansing, MI, [5]University of Wisconsin-Madison, Madison, WI (080)

Multiple weed species are resistant to more than one mode of action, a majority of which are post-emergence herbicides. Dicamba tolerant crops allow growers to apply dicamba herbicides over the top of actively growing soybeans. Although dicamba tolerant crops can provide an effective weed management option, risk of dicamba off-site movement to sensitive crops is a concern (Foster et al, 2019). One such method of off-site movement is through volatility, or the physical change of a liquid into a gas. Dicamba is one post-emergence herbicide that, when moved off target, can result in severe damage to sensitive crops, like soybean. With the release of dicamba tolerant crops, many new premixes are beginning to include dicamba as one mode of action. This study was conducted to compare volatility and herbicide vapor movement of new dicamba premixes and additives. Field studies were conducted in Alabama, Georgia, Michigan, Mississippi, Missouri, and Wisconsin using low tunnels. Greenhouse soil flats filled with field soil were treated with each premix and then placed between two rows of soybean. The soil flats were covered by a low, open ended tunnel covered with plastic for a period of 48 hr. An air sampler, calibrated to pull 3L of air per minute, was connected to a polyurethane foam tube (PUF) and was placed under each low tunnel. Treatments included 2.0 lb ae/A dicamba (XtendiMax + Vaporgrip) + 4.5 lb ae/A glyphosate + 4% v/v MON 51817 + 2% v/v Intact; 6.5 lb ae/A dicamba + glyphosate premix (MON 301621); 6.5 lb ae/A MON 301621 + 2.34 lb ae/A glufosinate (Liberty); 6.0 lb ae/A dicamba + glyphosate premix (MON 119151); 6.0 lb ae/A MON 119151 + 4% v/v MON 51817; 6.0 lb ae/A MON 119151 + 2.34 lb ae/A Liberty; 6.0 lb ae/A MON 119151 + 2.34 lb ae/A Liberty + 4% v/v MON 51817 + 2% v/v Intact; and an untreated check. Visual injury ratings and plant heights were taken in 31-centimeter increments from the plot center, where the treated soil flats were located, out to 762 cm. At 14 DAT, the combination of Xtendimax + Powermax + MON 51817 + Intact showed less injury than both MON 301621 and MON 301621 + Liberty, regardless of distance. No difference in visual injury was observed between MON 301621 and MON 301621 + Liberty at both 14 and 28 DAT. Visual injury from MON 119151 alone or with Liberty did not differ regardless of distance at both 14 and 28 DAT. The addition of MON 51817 to MON 119151 alone

or in combination with Liberty reduced visual injury at both 14 and 28 DAT. The combination of Xtendimax + Powermax + MON 51817 + Intact showed similar visual injury to MON 119151 + MON 51817 and MON 119151 + Liberty + MON 51817 + Intact at both 14 and 28 DAT. No differences in visual injury were observed among treatments at distances beyond 427 cm at either evaluation interval. The addition of MON 51817 to MON 119151 alone or MON 119151 + Liberty + Intact reduced dicamba concentrations to near 50 ng/PUF. MON 119151 + Liberty (253 ng/PUF) and MON 119151 (195 ng/PUF) showed the highest levels of dicamba volatility. There were no differences from the untreated check or Xtendimax + Powermax + MON 51817 + Intact when combining MON 119151 + Liberty + MON 51817 + Intact, or when combining MON 119151 + MON 51817. MON 301621 (106 and 81 ng/PUF) treatments were less volatile than MON 119151 treatments that did not contain MON 51817 (195 and 253 ng/PUF).

Impact of Dicamba+Various Postemergence Herbicide Tank-Mixes on Palmer Amaranth (*Amaranthus palmeri*) Control and Cotton Injury. Bradley J. Norris*[1], Darrin M. Dodds[1], Jacob P. McNeal[1], John J. Williams[1], Steven D. Hall[2], William J. Rutland[2]; [1]Mississippi State University, Mississippi State, MS, [2]Mississippi State University, Starkville, MS (081)

Proliferation of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) throughout the Southeast United States, necessitates continued evaluation of cost-effective control methods. New technologies have been developed to combat glyphosate-resistant Palmer amaranth. The Xtendi® system allows for postemergence application of dicamba to cotton varieties containing XtendFlex® technology. Experiments were conducted in 2019 to evaluate Palmer amaranth control and cotton injury in Mississippi. Experiments were conducted at Hood Farms in Dundee, MS. The following POST herbicide programs were evaluated in conjunction with fluometuron at 1.1 kg ai/ha PRE to evaluate Palmer control and cotton injury; 1) dicamba 0.56 kg ai/ha + glufosinate 0.66 kg ai/ha + intact 0.5% v/v; 2) dicamba 0.56 kg ai/ha + acetochlor 1.3 kg ai/ha; 3) dicamba 0.56 kg ai/ha + clethodim 0.1 kg ai/ha + NI surfactant 0.25% v/v + intact 0.55 v/v; 4) glyphosate 1.3 kg ai/ha + dicamba 0.56 kg ai/ha + intact 0.5% v/v; 5) glyphosate 1.3 kg ai/ha + dicamba 0.56 kg ai/ha + glufosinate 0.66 kg ai/ha + intact 0.5% v/v; 6) glyphosate 1.3 kg ai/ha + dicamba 0.56 kg ai/ha + acetocholor 1.3 kg ai/ha + intact 0.5% v/v; 7) glyphosate 1.3 kg ai/ha + dicamba 0.66 kg ai/ha + clethodim 0.1 kg ai/ha + NI surfactant 0.25% v/v + intact 0.5% v/v; 8) glyphosate 1.6 kg ai/ha + dicamba 0.55 kg ai/ha; 9) glyphosate 1.6 kg ai/ha + dicamba 0.55 kg ai/ha + glufosinate 0.66 kg ai/ha + intact 0.5% v/v; 10) glyphosate 1.6 kg ai/ha + dicamba 0.55 kg ai/ha + clethodim 0.1 kg ai/ha + NI surfactant 0.25% v/v + intact 0.5% v/v; 11) glyphosate 1.9 kg ai/ha + dicamba 0.73 kg ai/ha; 12) glyphosate 1.9 kg ai/ha + dicamba 0.73 kg ai/ha + glufosinate 0.66 kg ai/ha; 13) glyphosate 1.9 kg ai/ha + dicamba 0.73 kg ai/ha + acetochlor 1.3 kg ai/ha; 14) glyphosate 1.9 kg ai/ha + dicamba 0.73 kg ai/ha + clethodim 0.1 kg ai/ha + NI surfactant 0.25% v/v. The POST applications were made to 4 to 5 node cotton and Palmer amaranth was around 10cm in height. All applications were made with a CO2-powered backpack sprayer equipped with Turbo Teejet induction spray tips and an application pressure of 324 kPa. Visual evaluations of Palmer amaranth control was taken at 14 and 21 DAA. Crop injury was visually evaluated 3, 7, 14 and 21 DAA. Data were subjected to analysis of variance and means were separated using Fischers Protected LSD at a=0.05. No POST herbicide application resulted in significant crop injury. The application of fluometuron PRE, along with a POST application of: glyphosate + dicamba + acetochlor + intact provided 90% palmer amaranth control up to 21 DAA. All the other treatments provided similar control up to 14 DAA and decreased control was observed at 21 DAA. Palmer amaranth can be effectively controlled through a planned PRE/POST weed management program, containing multiple modes of action. Residual herbicides are recommended as part of weed control programs to promote herbicide resistance management.

Evaluation of *Echinochloa crus-galli* Sensitivity to Florpyrauxifen-benzyl. Grant L. Priess*, Chad Brabham, Jason K. Norsworthy; University of Arkansas, Fayetteville, AR (082)

Abstract not available

Determining Duration of Residual Control of Soil-applied Herbicides in Cotton. Justin S. Calhoun*[1], J Connor Ferguson[2], Kayla L. Broster[2], Zachary R. Treadway[2], Luke H. Merritt[2], Michael T. Wesley Jr.[2]; [1]Mississippi State University, Starkville, MS, [2]Mississippi State University, Mississippi State, MS (083)

Abstract not available

Palmer Amaranth (*Amaranthus palmeri*) and Tarnished Plant Bug (*Lygus lineolaris*) Control with Various Dicamba + Insecticide Tank-Mixes in Cotton. Angus L. Catchot*[1], Darrin M. Dodds[2], Jacob P. McNeal[2], John J. Williams[2], Bradley J. Norris[2], Steven D. Hall[1], William J. Rutland[1]; [1]Mississippi State University, Starkville, MS, [2]Mississippi State University, Mississippi State, MS (084)

A field experiment was conducted in 2018 and 2019 to evaluate the effect of carrier volume and spray droplet size on the efficacy of dicamba + insecticide tank mixtures to control Palmer amaranth (*Amaranthus palmeri*) and Tarnished plant bug (*Lygus lineolaris,* L.) in cotton (*Gossypium hirsutum*). This experiment consisted of field two locations: the Delta Research and Extension Center in Stoneville, Mississippi, and Hood Farms in Dundee, Mississippi. Four row plots were planted with a single cotton variety: DP 1646 B2XF, and plot dimensions were 3.9m x 14.2m (Stoneville, MS) and 3.8m x 9.1m (Dundee, MS). Applications were made with a Capstan Pinpoint® Pulse-Width Modulation (PWM) sprayer on a high-clearance Bowman Mudmaster at a ground speed of 14.5 km hour^{-1} and were initiated prior to first bloom. A single formulation of dicamba: (XtendiMAX® with VaporGrip) applied at 1.5 kg ha^{-1}, and two insecticides: thiamethoxam (Centric® 40WG) applied at 0.14 kg ha^{-1}, and sulfoxaflor (Transform® WG) applied at 0.11 kg ha^{-1} were chosen. This experiment utilized two carrier volumes: 140 and 280 L ha^{-1} and two droplet sizes: 200µm and 800µm. Pesticide - Carrier Volume - Droplet Size treatment combinations included [1] dicamba-141 L ha^{-1}-800 µm, [2] dicamba + thiamethoxam-141 L ha^{-1}-800 µm, [3] dicamba + sulfoxaflor-141 L ha^{-1}-800 µm, [4] dicamba + thiamethoxam-280 L ha^{-1}-800 µm, [5] dicamba + sulfoxaflor-280 L ha^{-1}-800 µm, [6] thiamethoxam-141 L ha^{-1}-200 µm, [7] thiamethoxam-141 L ha^{-1}-800 µm, [8] sulfoxaflor-141 L ha^{-1}-200 µm, [9] sulfoxaflor-141 L ha^{-1}-800 µm. Each replication contained both a weed/pest free check in addition to an untreated control. Drop cloth counts for Tarnished plant bugs (adults and nymphs) were taken at 3 and 7 DAT. Visual Palmer amaranth control (0-100) was evaluated at 7, 14, 21, and 28 DAT, and visual cotton injury (0-100) was evaluated at 7, 14, and 21 DAT. Seed cotton yield was collected using a spindle picker modified for plot research. Additionally, 25 boll -samples were collected prior to mechanical

harvest and ginned on a laboratory micro-gin to determine lint turnout. The experimental design was a Randomized Complete Block and data were analyzed using PROC MIXED in SAS v. 9.4. Means were separated using Fisher's Protected LSD at an alpha level of 0.05. At 7, 14, 21, and 28 DAT, visual Palmer amaranth control varied due to treatment (p = < 0.0001). All treatments resulted in significantly less Palmer amaranth control relative to the weed free check and significantly greater control relative to the untreated control. Dicamba + sulfoxaflor applied at a carrier volume of 280 L ha^{-1} resulted in significantly greater control (= 27.5%) relative to dicamba + sulfoxaflor when applied at 141 L ha^{-1}. Across carrier volume and tank-mix, all applications resulted in the same level of Palmer amaranth control as dicamba when applied alone at a carrier volume of 141 L ha^{-1}. Across carrier volume, droplet size, and tank mix, no effect on Tarnished plant bug counts was observed 3 DAT, and no effect on adults was observed 7 DAT. However, 7 DAT Tarnished plant bug nymphs varied due to treatment (p = 0.0014). Dicamba + sulfoxaflor applied at a carrier volume of 141 or 280 L ha^{-1} with 800µm droplets, sulfoxaflor applied at 141 L ha^{-1} with either 200 or 800µm droplets, and thiamethoxam applied at 141 L ha^{-1} with 800 µm spray droplet sizes all resulted in the same level of control as the pest free check, and significantly more control than both the untreated control and dicamba + thiamethoxam applied at 141 L ha^{-1} with 800µm droplet sizes. Across carrier volume, droplet size and tank-mix, no effect on visual cotton injury, turnout, or seed cotton yield was observed. These data indicate dicamba + sulfoxaflor applied at a carrier volume 280 L ha^{-1}, or dicamba + thiamethoxam applied at 141 or 280 L ha^{-1} resulted in the same level of Palmer amaranth control relative to dicamba when applied alone at 141 L ha^{-1}. Additionally, dicamba + sulfoxaflor applied at a carrier volume of 141 or 280 L ha^{-1} with 800 µm droplets resulted in the same level of tarnished plant bug control 7 DAT as thiamethoxam applied at a carrier volume of 141 L ha^{-1} with 800 µm spray droplets, or sulfoxaflor applied at a carrier volume of 141 L ha^{-1} with either 200 or 800µm droplets, primarily through controlling nymphs. These date indicate multiple options exist with respect to Palmer amaranth and Tarnished plant bug control with dicamba + sulfoxaflor and thiamethoxam tank-mixes relative to dicamba, sulfoxaflor, or thiamethoxam when applied alone.

Effect of Late-Season Applied Herbicide Tank-Mixtures on Control and Seed Production of Palmer Amaranth in Postharvest Wheat Stubble. Rui Liu*, Vipan Kumar, Natalie Aquilina, Taylor Lambert; Kansas State University, Hays, KS (085)

Due to widespread evolution of glyphosate resistance, the late-season control of Palmer amaranth (*Amaranthus palmeri*) in wheat stubble has become a serious challenge for growers in the Central Great Plains, including Kansas. The objective of this study was to determine the effectiveness of alternative POST herbicide tank-mixtures (with multiple modes of actions) for late-season control of Palmer amaranth in postharvest wheat stubbles. Field experiments were conducted at Kansas State University Agricultural Research Center in Hays, KS in 2019. The experimental site was planted with winter wheat in fall 2018 and harvested in 2019. The study site had a natural seedbank of Palmer amaranth that emerged immediately after wheat harvest. All selected herbicide programs were tested 3 weeks following wheat harvest, when Palmer amaranth plants had attained a height of 24 to 30 cm and were showing sign of inflorescence initiation. The study was conducted in a randomized complete block design with 4 replications. Twenty-four herbicide treatments. including glyphosate, dicamba, 2,4-D, atrazine, paraquat, metribuzin, flumioxazin, sulfentrazone, saflufenacil, fluroxypyr, and premixes of sulfentrazone+ pyroxasulfone, flumioxazin+ metribuzin, pyrasulfotole + bromoxynil applied alone or in tank-mixtures were tested at field-use rates. Percent visible control was assessed at 2, 4, and 8 weeks after treatment (WAT) by using a rating scale of 0-100%, where 0 equals to no control and 100% equals to complete control/plant death. The aboveground Palmer amaranth biomass was hand-harvested using a 1-m^2 quadrat placed at the center of each plot to determine the shoot dry weight and seed production at 8 WAT. All tested herbicide programs, except fluroxypyr alone and a tank-mixture of atrazine plus pyrasulfotole + bromoxynil provided > 88 % control of Palmer amaranth across at 8 WAT. In contrast, late-season control of Palmer amaranth did not exceed 71% at 8 WAT with fluroxypyr alone or a tank-mixture of atrazine plus pyrasulfotole + bromoxynil treatments. Consistent with percent visible control, majority of those tested programs significantly reduced shoot dry weights (>77% reduction) and seed production (>93% reduction) of Palmer amaranth compared to nontreated weedy check. These results suggest that several alternative POST herbicide programs exist that should be proactively utilized by the growers for effective late-season control of Palmer amaranth in postharvest wheat stubble.

Weed Species Identification Using Multispectral Imagery. Wesley Everman*, John Sanders; North Carolina State University, Raleigh, NC (086)

Abstract not available

Implications of Multi-Tactic Weed Management Strategies to Deplete Glyphosate-Resistant Tall Waterhemp Seed Bank in Corn-Soybean Rotations in the Midwest. Ramawatar Yadav*, Prashant Jha, Damian D. Franzenburg, James M. Lee, Iththiphonh A. Macvilay; Iowa State University, Ames, IA (087)

Waterhemp [*Amaranthus tuberculatus* (Moq.) J. D. Sauer] is one of the most troublesome weeds in corn-soybean production systems of the Midwest. Due to evolution of 6-way multiple herbicide-resistant waterhemp populations, there is an urgent need to develop ecologically based, multi-tactic weed management strategies at a cropping systems level. Field experiments were initiated in the summer 2019 at two sites: ISU Curtiss Farm in Ames, IA and a grower field in Bruner, IA. The objectives of this study were to: 1) implement herbicide-based marginal, aggressive, and aggressive plus weed removal programs for glyphosate-resistant (GR) waterhemp control in the corn phase (2019) and 2) evaluate the impact of previous year's program in conjunction with cereal rye cover crop (cover crop vs. no cover crop) and row spacing (76-cm vs. 38-cm soybean rows) on GR waterhemp seed bank depletion in the soybean phase of the rotation (2020). A split-split plot design was used with four replications. In the corn phase, efficacy of three herbicide programs (HP) as a main plot factor was evaluated. Marginal HP included S-metolachlor (1788 g ai ha^{-1}) PRE followed by (fb) glyphosate (1261 g ai ha^{-1}) POST. Aggressive HP included saflufenacil (50 g ai ha^{-1}) + pyroxasulfone (91 g ai ha^{-1}) PRE fb glufosinate (656 g ai ha^{-1}) + S-metolachlor (1539 g ai ha^{-1}) POST. In the aggressive plus weed removal program, any late-season waterhemp survivors from the aggressive herbicide treatment were hand-removed to prevent late-season seed bank additions. Marginal HP provided =35% control of GR waterhemp at 6 weeks after PRE (WAPRE) or 2 weeks after POST (WAPOST). Aggressive HP provided =97% control of GR waterhemp at 6 WAPRE or 2 WAPOST; however, GR waterhemp density increased to 6 plants

m^{-2} by 9 WAPOST in the absence of hand removal treatment. These results indicate that a late-season management tactic is required to prevent GR waterhemp seed bank additions even with an aggressive herbicide program in corn. Treatment effects on the GR waterhemp seed bank in the soybean phase of the rotation (Objective 2) will be evaluated in the 2020 growing season.

History and Current Status of Herbicide-Resistant Waterhemp [*Amaranthus tuberculatus* (Moq.) J. D. Sauer] in Iowa Corn and Soybean Fields. Prashant Jha*, Ryan C. Hamberg, Iththiphonh A. Macvilay, James M. Lee, Ramawatar Yadav, Avery J. Bennett, Edward S. Dearden, Damian D. Franzenburg; Iowa State University, Ames, IA (088)

The escalating spread of herbicide-resistant waterhemp [*Amaranthus tuberculatus* (Moq.) Sauer] populations has become a production challenge in corn-soybean based crop rotations of Iowa and the Midwest. With the evolution of waterhemp resistance to major herbicide groups used in corn and soybean, there are a limited number of herbicide options left to control this weed. The early detection and rapid response is key to preventing further spread of resistance. In order to fulfill this goal, a state-wide survey was conducted in Iowa in fall 2019 to collect ~250 waterhemp populations (seeds) from georeferenced sites used in the 2013 survey. The objectives were to: 1) compare the temporal changes in baseline sensitivity of waterhemp populations collected in 2013 vs. 2019 to auxinic herbicides (dicamba, 2,4-D), HPPD inhibitors, PPO inhibitors, chloroacetamides, glyphosate, and glufosinate; 2) detect the level of evolved resistance in selected 2019 waterhemp populations using whole plant dose-response and molecular diagnostic assays. Results from the 2013 survey indicated that 5-way resistant waterhemp populations had evolved in Iowa corn and soybean fields. Screening of 2019 populations is currently under progress. This information will allow us to develop proactive strategies to contain further spread of herbicide resistance, more importantly populations with resistance to multiple herbicides and understand the long-term impact of management practices on weed resistance evolution. Overall, this project will emphasize the need to implement diverse integrated weed management (IWM) programs to achieve sustainability.

Benefit of Dicamba in Early Postemergence Herbicide Tank-mixtures. Brent S. Heaton*, Mark L. Bernards; Western Illinois University, Macomb, IL (089)

Off-target movement of dicamba becomes more problematic when it is applied in late June or early July. Dicamba tank-mixed with residual herbicides applied PRE or early-POST may offer improved control of troublesome weeds while minimizing some of the risks of off-target movement. Our objective was to quantify the weed control benefits of dicamba tank-mixed with residual herbicides applied PRE or early-POST. Two non-crop bioassays, two early-POST corn trials, and four soybean trials (PRE only or PRE and early-POST) were conducted on Western Illinois University's Agronomy Farm in Macomb, IL. Visual weed control estimates were made to measure treatment effects. Dicamba tank-mixed with residual herbicides frequently increased the percent control of waterhemp, cocklebur, common lambsquarters, sunflower, and morningglory when compared to the residual herbicides applied alone. In some situations tank-mixing dicamba extended the duration of control. Individuals who wish to use dicamba should apply it with residual herbicides before corn or soybean reach the V2 growth stage to improve early season weed control.

WSWS Project 4. Teaching and Technology Transfer

WSSA Section 7. Teaching & Extension/Teaching and Technology Transfer

Can Trunk Paint Mitigate Herbicide Damage in Young Almond Trees? Drew A. Wolter*[1], Danielle M. Lightle[2], Brad Hanson[3]; [1]University of California, Davis, Sacramento, CA, [2]University of California Cooperative Extension, Oroville, CA, [3]University of California, Davis, Winters, CA (139)

Weed control in young orchards is critical for good establishment and early growth, which can impact long-term success of the crop. Postemergence herbicides that are safe on older trees, with hardened and mature bark, may not be safe on young almond trees, with thinner and tender green bark. A standard pomological practice in California almond, walnut, and prune production is to apply white latex paint to the lower 2 to 3 feet of the trunk, in an effort to protect them from postemergence herbicides; however, research on the efficacy of this practice is lacking. A field experiment was conducted in Arbuckle, CA to evaluate the impacts of latex paint on sensitivity to herbicide injury in young almond trees. The experimental design was a split plot with a 4 by 7 factorial combination trunk protection and herbicide treatments and four replicates of each treatment combination. For the trunk protection main effect, second-leaf almond trees given one of four categories of trunk protection: old paint (9-week old), new paint (2-day old), no paint (hardened-off for 9 weeks), and cartoned. The cartons for the "no paint" and "old paint" treatments were removed for the first time, nine weeks before the herbicide applications, exposing green bark. Valspar interior latex paint, diluted 50:50 with water, was then applied using a painter's mitt to the group of trees in the old paint treatment. This also allowed for the no paint treatment to harden off for nine weeks prior to the herbicide application. Two days prior to the herbicide applications, the cartons for the new paint treatments were removed for the first time and the trunks were painted. The cartoned treatments in this experiment never had their cartons removed. On June 20th, 2019 herbicide treatments including two rates each of glyphosate (Roundup PowerMAX), glufosinate (Rely 280), or a tank mix of both were applied. Herbicide applications were made using a CO_2 backpack sprayer at 35 psi, and a spray volume of 20 gallons/acre. A single nozzle was held 18 inches from the trunk, moving vertically (from top to bottom) for one second on both the eastern and western sides of the trees. Results from the 2019 trial indicated that paint as a trunk protection method may not provide significant protection from glyphosate or glufosinate. Tree stress caused by trunk-applied herbicides was lowest in the painted and non-painted treatments where trunks were allowed to harden off for nine weeks, which suggests that hardening of the bark is key to mitigating herbicide damage in young trees. For example, trees treated with the top-of-label-rate, tank-mix of glyphosate and glufosinate had 4-22% greater trunk damage than trees that were not painted. The most efficacious trunk protection option for young almonds trees is to install a carton; however, when cartons are eventually removed green bark may be present and susceptible to herbicide injury. Therefore, a key grower recommendation of this research is to time postemergence herbicide applications either before cartons are removed or after trunks have had time to harden off after carton removal, to minimize the risk of herbicide damage.

Simulation Modeling as Decision-Aid for Farmers: Adapting Weed Management to a Changing Climate. Ruth Sexton*, Eric Gallandt; University of Maine, Orono, ME (140)

Paper withdrawn

Identifying Herbicide Injury in Potato. Andrew P. Robinson*; North Dakota State University / University of Minnesota, Fargo, ND (141)

The number of herbicide injury problems in potato are more common place, causing many questions by potato growers. Injury from herbicides can be a result of soil carryover, herbicide residues in seed, or exposure of plants to herbicides. As a result, potatoes can have poor emergence, chlorosis, necrosis, growth reduction, misshapen tubers, reduced yield and non-acceptable residues. The objective of this poster is to demonstrate various herbicide injury symptoms to assist potato growers in improved identification. Determining if injury is caused by herbicides or another source will be important in managing and marketing potatoes.

Useful Wild Plants of Texas....A Resource for Weed Scientists That Need to Know More Than How to Kill Plants. John D. Byrd, Jr.*; Mississippi State University, Mississippi State, MS (142)

As weed scientists our focus is often on killing undesirable plants in a particular site. But there are times we need to know more about a plant or genera of plants. One question that arises with some frequency is “Is the plant toxic?” or “Is it native or exotic?” and sometimes “What can it be used for?” or “Did Native Americans use it?” Useful Wild Plants of Texas, the Southeastern and Southwestern United States, the Southern Plains, and Northern Mexico is a resource to help answer to those questions. Four volumes have been published with the goal to document written descriptions of species and common names, color photographs, distribution maps, ethnobotanical uses as food for human or livestock, medicinal value, fiber, fuel, building, dye, based on archeological and historic fact. There is also information on landscape uses, pollinator habitat, cultural habitat, crop potential, plant toxicity, and potential weediness on 4000 species of native and naturalized plants. Volume 1 covers covers 267 species in 78 genera *Abronia* to *Arundo*; Volume 2 provides detailed information on 254 species in the 79 genera *Asclepias* to *Canavalia*; Volume 3 covers 129 species in the 23 genera *Canna* to *Celtis*; while Volume 4 covers 175 species in the 66 genera *Cenchrus* to *Convolvulus*. These clothbound encyclopedias can be ordered online at https://www.usefulwildplants.org or contacting Useful Wild Plants, Austin, Texas at 512-478-5243. Weed scientists that have a desire to know more about a plant than simply what kills it as well as individuals that teach weed biology and ecology, train Master Gardeners, or deal with human or livestock plant poisoning will find these references invaluable.

Update to the Herbicide Resistance Action Committee Classification on Mode of Action. Rex A. Liebl*[1], Jeffrey Epp[2], Bernd Laber[3], Hubert Menne[3], James Morris[4], Matthias Witschel[5]; [1]BASF Corp, Raleigh, NC, [2]Corteva Agriscience, Indianapolis, IN, [3]Bayer AG Crop Science, Frankfurt, Germany, [4]Syngenta, Bracknell, United Kingdom, [5]BASF SE, Ludwigshafen, Germany (143)

The Herbicide Resistance Action Committee (HRAC) sponsored a Working Group comprised of senior herbicide chemists and agronomists at Corteva, Bayer Crop Science, Syngenta and BASF to update the HRAC mode of action classification including “The World of Herbicides” poster. Changes since the last update in 2010 include the addition of 14 new actives, rationalization of chemical family names, and four new or updated modes of action: inhibition of fatty acid thioesterase (cinmethylin), inhibition of homogentisate solanesyltransferase (cyclopyrimorate), inhibition of solanesyl diphosphate synthase (aclonifen), and inhibition of serine-threonine protein phosphatase (endothall).

University of Tennessee Dicamba Stewardship Education Efforts. Larry Steckel, Ginger Rowsey*; University of Tennessee, Jackson, TN (144)

In trying to manage Palmer amaranth, cotton and soybean growers in Tennessee embraced the Xtend (dicamba-tolerant crop) weed management system. In 2017 an estimated 75% of cotton and 60% of soybean acres were planted to Xtend varieties. Unfortunately, most applicators struggled to keep dicamba in the target field when applying this product. The Tennessee Department of Agriculture (TDA) fielded 136 drift complaints. Officials estimated dicamba-drift damages were spread across more than 400,000 off-target acres - earning Tennessee the undesirable ranking of third in the nation for dicamba damages. As a result of all the off-target issues some growers elected to plant Xtend soybeans in 2018 simply out of self-defense while many elected to plant Xtend crops due to effective weed control. As a result of all the off-target dicamba issues in 2017, the EPA ruled that all dicamba applicators must participate in dicamba-specific training in 2018. The Tennessee Department of Agriculture looked to Tennessee Extension to lead the training in our state. Our mission was to educate every applicator on the nature of dicamba, the label requirements and the new rules that had been enacted by the State of Tennessee. The list of what applicators needed to know was lengthy and cumbersome. Remembering all the steps to take to avoid dicamba drift and volatilization would be challenging. But they had to remember these steps as many thousands of acres of non-tolerant soybeans, fruits, vegetables, trees and ornamental plants were in the line of fire. We created a training module that could be played as a video. Trainers also had the option to lead the training as a PowerPoint presentation. We distributed this module to all agricultural Extension agents, who held in-person trainings in their counties. We also provided the training online. We maintained a web page on our UT Institute of Agriculture website that kept a running list of all in-person training opportunities as well as a link to the online training. During the months of February and March we also made weekly blog posts about training opportunities and resources through our UTCrops.com news blog. In addition to a list of trainings, our Dicamba Resources web page included links to spray guidelines, record forms, registrant websites and informational videos. Before and during spray season, we anticipated potential issues and created nine informational YouTube videos to proactively address these topics. These videos were shared through our UTCrops news blog, social media and our Dicamba Resources page to keep dicamba best practice guidelines in front of our audience throughout the year. We created an online report to be shared with homeowners in the event of dicamba drift damage to trees, gardens and landscape plants. By the time the 2018 and 2019 spray seasons began, over 2,800 and 2,600 applicators, respectively, had viewed our training modules. Their efficacy can in part be attributed to the reduction of complaints and acres affected by dicamba drift. Dicamba drift complaints went from 136 complaints on 400,000 acres in 2017 to 52 complaints on 70,000 acres in 2018 and 22 complaints and 30,000 acres in 2019. University's education efforts promoted making good decisions with dicamba applications and was a reason for fewer drift complaints in 2018 and 2019. This reduction in dicamba drift issues was also due to more Xtend soybeans being planted in Tennessee in 2018 and 2019 compared to 2017 and therefore fewer sensitive soybeans in harms way. Clearly, there is still room for improvement as 22 complaints, which occurred mostly on high value crops and homeowners' vegetation, is still too many. This is especially true when prior to the Xtend system being available Tennessee averaged less than 1 dicamba damage complaint annually.

Montana Noxious Weed Survey: Has 25 Years of Education Been Effective? Shantell A. Frame-Martin*[1], Jane Mangold[2], Eric Raile[2]; [1]Montana Noxious Weed Education Campaign, Bozeman, MT, [2]Montana State University, Bozeman, MT (145)

Education is often touted as one of the most important aspects of noxious weed management, yet there is little evidence to show its effectiveness. In 1994 a general population survey was conducted in Montana to evaluate Montanans' knowledge of noxious weeds. The results of the survey showed that Montanans were lacking in general knowledge about noxious weeds, including how they spread and their ecological impacts. In response to the survey, a statewide noxious weed education campaign was created in 1995. The campaign coordinates noxious weed education and outreach among federal, state, and local entities. To evaluate effectiveness of 25 years of noxious weed education, a survey similar to the 1994 survey was distributed throughout Montana in 2019. We used a mail questionnaire and received 830 responses, with an overall response rate of 18%. Results showed that Montanans are interested in the topic of noxious weeds and interest is evenly distributed across different areas of the state, but interest is somewhat less for younger adults and women. There has been an increase in Montanans' knowledge about noxious weeds over the last 25 years. In 1994, 67% of respondents reported that they “knew little or nothing” about noxious weeds compared to 48% in 2019, a 19% decrease. Furthermore, 40% of respondents said that their knowledge has increased “a little” or “a lot” in the last 5 years. Respondents indicated that family and friends are the most frequent source of learning, and the internet is the most popular resource when searching for information about noxious weeds. Respondents who have seen different forms of noxious weed advertisements are more likely to engage in behaviors to stop weed spread. Our project provides evidence that noxious weed education is beneficial, and it charts a course for improved outreach in the future.

Undergraduate Students Self-Assess Learning Gains. Karen A. Renner*; Michigan State University, East Lansing, MI (146)

Undergraduate students enter agronomy and weed science courses with differing backgrounds in academic coursework and work experiences. Instructors strive for students to achieve the learning outcomes for their courses by implementing various teaching strategies and technologies. Grades reflect how well a student knows the course material, but grades do not measure learning gains. Having students self-assess their personal learning gains in a course gives instructors an opportunity to see where and to what degree course content contributed to improving student knowledge. Instructors can also determine if learning gains differ based on student major and if course content needs to have increased rigor to improve learning gains.

Efforts in Weed Management Outreach for Urban &Amp; Community Audiences in California. Karey Windbiel-Rojas*[1], Maggie Reiter[2], John A. Roncoroni[3]; [1]University of

California Statewide IPM Program, Davis, CA, [2]University of California Cooperative Extension, Fresno, CA, [3]University of California Division of Agriculture and Natural Resources, Napa, CA (147)

Extending science-based information to residential audiences and landscape managers on weeds and their management is a constant challenge. California continues to experience new regulations, troublesome weeds, new invasive weed species, new herbicides on the market, as well as changing public opinion about herbicides, especially glyphosate. To educate people who manage weeds and other pests in non-agricultural settings, in 2007 the University of California Statewide Integrated Pest Management Program (UC IPM) established the Urban and Community IPM group to increase efforts on reaching the ever-growing urban population in California, to help protect human health and the environment by reducing risks caused by pests and their management, especially the use of pesticides. Since then, UC IPM has devised innovative methods to deliver information to end users. Efforts include creating and disseminating touch-screen interactive computer kiosks in libraries, retail stores where people purchase herbicides; hands-on weed identification training for various audiences; increasing weed-focused publications and educational tools in English and Spanish; and enhancing our home, garden and landscape web pages.

The Weedy and Invasive Plant Species Community of the American Society of Agronomy: Activities and Opportunities. Anil Shrestha*[1], Sharon Clay[2]; [1]California State University, Fresno, Fresno, CA, [2]South Dakota State University, Brookings, SD (148)

The Weedy and Invasive Plant Species Community is an American Society of Agronomy (ASA) community within the Agronomic Production Systems Section. The community consists of 555 members led by a chair and vice-chair who are elected to serve for two years, the first year as vice-chair and the second year as chair. This community has the potential to not only retain current members, but also attract new members and fulfill the other purposes outlined by the society. The interests of the community are in understanding the ecology of weedy and invasive plants in managed ecosystems and the development of sustainable approaches to manage them. In particular, this community has an interest in the basic principles of integrated weed management and focuses on an adaptive management framework such as plant identification, spatiotemporal weed distribution patterns, new technology (e.g., biotech, geospatial tools, remote sensing), herbicide resistance, weed competition, regulatory issues of weed management, and restoration of native communities. The community does not replace WSSA but seeks to enhance and expand interactions and opportunities with allied agronomic disciplines, such as agronomists, soil scientists, certified crop advisors (CCAs), and crop physiologists. Each year, the community organizes a symposium during the ASA/CSSA/SSSA meetings. For example, a symposium on organic weed control had over 300 in attendance and the linked oral and poster sessions were also well attended. Many members of the community and others also publish papers in the 'Pest interactions in Agronomic Sections' in ASA's highly-acclaimed 'Agronomy Journal.' The community encourages those interested to join as members of the community and participate in our activities.

Unseen Flowers: Weed Macro Photography Update. Robert F. Norris*; University of California, Davis, Davis, CA (149)

Implementation of focus stacking in the last decade has revolutionized macro photography. Details of plant structures are revealed that were essentially impossible to document photographically using conventional macro photographic techniques. Advances in hardware and software used for focus stacking now permit higher magnification, faster shooting, and panoramic high-resolution images. Several manufacturers feature focus stacking built into their newer camera bodies, which makes taking the 'stack' of photographs both easier and much faster, without the use of a focusing rail. With the use of appropriate adapter rings, it is feasible to attach a microscope objective to the front of conventional camera lenses. The result is extreme magnifications of 5-fold, or even higher, depending on the chosen objective. The drawback to using microscope objectives are very shallow depth of field (e.g. 12 µ for 5x magnification), and no ability to use camera built-in focus stacking. If large images are required with a high level of magnification it is feasible to use software to assemble 'panoramas'. This requires the ability to change the position of the object, or the camera, between shooting stacks using a two-axis rail. The multiple stacked images are later combined using photographic software.

National Pesticide Safety Education Center (NPSEC): Supporting Territory Pesticide Safety Education Programs (PSEPs). Kerry Richards*[1], Carroll Moseley[2]; [1]National Pesticide Safety Education Center, Port Matilda, PA, [2]Syngenta, High Point, NC (150)

The National Pesticide Safety Education Center (NPSEC) was established in February of 2017. NPSEC seeks to strengthen the national system of university extension Pesticide Safety Education Programs (PSEPs) by improving the quality, consistency, and accessibility of educational offerings. Also strengthening PSEPs by promoting collaboration and leveraging of educational resources, learning assessment tools, and increasing revenue generation. The Center received start-up funding from CropLife Foundation and crop protection companies BASF, Bayer, Corteva, and Syngenta. Currently NPSEC is self-supporting through funding provided by cooperative projects and the availability of EPA and other grant funding. The poster will provide an update and highlights of progress since the inception of NPSEC. Highlights include development and delivery of materials for on-line and in person paraquat training, similar educational materials for PSEPs, and a NPSEC store that provides access to pesticide safety education and training materials.

WSWS Project 5. Basic Biology and Ecology

WSSA Section 9. Weed Biology and Ecology

Germination Response of Downy Brome, Wild Oat, and Italian Ryegrass to Gibberellic Acid in Palouse Silt Loam. Madisyn R. Beaudoin*, Rachel J. Zuger, Ian Burke; Washington State University, Pullman, WA (160)

Winter annual grass downy brome (*Bromus tectorum* L.) and Italian ryegrass (*Lolium multiflorium* Lam.) and summer annual wild oat (*Avena fatua* L.) currently plague the dryland wheat production systems of the Pacific Northwest (PNW). Gibberellic acid (GA_3), is a naturally occurring plant growth hormone which can be used to alleviate seed dormancy. Currently, it is used to control plant growth stages such as altering stem elongation, root extension, flowering and fruit development, and pollination processes. A greenhouse study was conducted to assess the response of new and old seed of the three grass species to GA_3 (RyzUp Smartgrass) in Palouse Silt Loam field soil. Treatments of GA_3 (0, 1.4, 14, 28, 56 g ai ha^{-1} and GA_3 soak) were applied to the soil surface and immediately incorporated with approximately 11,287 L ha^{-1} water. Seedlings were quantified 1, 2, and 3 WAT to evaluate germination. At 4 WAT final counts were recorded, and aboveground biomass was harvested. Treatment and age of seed significantly ($P < 0.001$) affected the response of downy brome counts 4 WAT. Italian ryegrass counts at 4 WAT were significantly ($P = 0.0150$) impacted by both rate of GA_3 and age of seed. Wild oat germination was not affected by GA_3, but by age of seed, older seed resulted in more germination than new seed. Based on results, GA_3 could be used as an effective management tool for older downy brome and Italian ryegrass seeds in the weed seedbanks of dryland wheat production systems of the PNW.

Effects of Tillage and Pesticides on Weed Seedling Emergence Over a Growing Season.
Samuel A. Palmer*[1], Benjamin Fehr[2], Richard G. Smith[2]; [1]University of New Hampshire, Epsom, NH, [2]University of New Hampshire, Durham, NH (161)

Pesticide seed treatments (coating seeds with insecticides and/or fungicides, hereafter “PST”) are common in conventional maize and soybean production; however, little is known about how PST may affect the natural enemies of weeds and weed population dynamics. We conducted a field experiment in New Hampshire in which we planted identical genotypes of maize and soybean with and without PST under conventional and no-tillage and quantified the effects of these treatments on weed seedling emergence from the soil seed bank over the growing season. We did not detect an effect of PST on weed seedling emergence in the conventionally tilled system. In the no-tillage system, a greater number of weed seedlings emerged over the period after the final glyphosate application in the PST treatment compared to the control. These results suggest that PST use has the potential to alter weed communities in corn and soybean production systems. Research is underway to determine the mechanism(s) by which PST alters weed seedbank and emergent weed community dynamics.

Using Biology to Better Inform Marestail (*Conyza canadensis*) Management.
Ryan Collins*[1], Erin Haramoto[1], Karla L. Gage[2], Brent Sunderlage[2], Anita Dille[3], Reid Smeda[4]; [1]University of Kentucky, Lexington, KY, [2]Southern Illinois University Carbondale, Carbondale, IL, [3]Kansas State University, Manhattan, KS, [4]University of Missouri, Columbia, MO (162)

The importance of sustainable weed management practices continues to grow as farmers are increasingly faced with herbicide resistant weed populations. Marestail (*Erigeron canadensis*) is a problematic weed in soybean cropping systems that has developed resistance to multiple herbicide modes of action. Marestail is easiest to control shortly after emergence, and information on emergence timing will better inform management practices. Tracking marestail density throughout the year will allow comparisons to be made between different management practices, and provide validation to the efficacy of those management strategies. Objective 1 of this research is to determine how well cover crops (CC), herbicides, and combinations of the two suppress marestail emergence in a no-till soybean cropping system. We hypothesize that a CC will suppress fall marestail emergence more than synthetic herbicide applications. Objective 2 is to compare the yield and partial budget net returns (PBNR) of each management strategy to a weed free treatment and a common weed management program that many soybean farmers are employing Treatments contained fall and spring applied herbicides with different levels of residual activities, CC and combinations of the two. Two permanent quadrants were established in each plot, after fall CC were planted until soybean harvest the following year, where marestail seedlings were counted and removed. Cumulative marestail emergence in the field experiment was summed over two periods: prior to soybean planting (CC planting to CC termination) and after soybean planting (soybean planting to harvest). Environmental conditions were adequate in both years for marestail germination in the fall (October and early November), which suggests a CC or properly timed herbicide application would be needed to prevent emergence and a potentially over-wintering cohort. There was no state by treatment interaction on cumulative emergence in year one (October 2017 –August 2018), and a fall herbicide with residual activity management strategy suppressed marestail better than any other treatment. Prior to planting soybean in year two only, there was a significant state by treatment interaction. In year two prior to planting, IL saw significantly lower marestail emergence in plots with a CC compared to those without a CC and/or herbicide application, which supports our hypothesis. A fall herbicide application, without residual activity, may not align with fall emerging marestail, and was not as effective as a CC. Cumulative emergence after soybean planting was lower in plots with spring applied herbicides in both years. In KY, significant differences were found in yield and PBNR between the untreated control to the weed free treatment and the common farmer weed management program in both years. All treatments with a management strategy (CC and/or herbicides) had similar yields and PBNR. When comparing the IL PBNR data in year one, only the untreated check and the CC + fall tillage treatment were statistically different than the weed free treatment, yet all CC plots had lower PBNR than the common farmer weed management program. Year two IL yields and PBNR were more variable. The weed free treatment plots had lower than expected yields, only the untreated treatment yielded less. These findings suggest that adopting CC to a weed management program can reduce marestail populations, feasibly without lowering a farmer's bottom line. If resistant marestail populations plague a field, CC can be a less expensive option.

Evaluating Evapotranspiration and Growth of Palmer Amaranth (*Amaranthus palmeri*) in a Corn/Soybean and Non-crop Situation Under Subsurface Drip and Center-pivot Irrigation Systems. Jasmine M. Mausbach*[1], Suat Irmak[1], John Lindquist[1], Debalin Sarangi[2], Amit J. Jhala[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Wyoming, Powell, WY (163)

Palmer amaranth (*Amaranthus palmeri S. Watson*) (PA) is one of the most problematic and troublesome weeds in agronomic cropping systems in the United States. Several factors have enabled PA to become such a dominant and difficult-to-control weed, including its rapid growth rate and ability to tolerate adverse conditions. Literature regarding the evapotranspiration (ET) of PA in cropping systems does not exist. The objective of this study was to determine the effect of center-pivot (CP) versus subsurface drip irrigation (SDI) on ET of PA grown in corn, soybean, and under no-crop (fallow) situation in south central Nebraska. Field experiments were conducted in 2019 in the Irmak Research Laboratory's advanced irrigation engineering and evapotranspiration research facilities at UNL's South Central Agricultural Laboratory near Clay Center, NE. Twelve PA plants were transplanted one meter apart in the middle two rows of eight row soybean, corn, and fallow plots under CP and SDI. Weed-free soybean and corn plots were included for comparison. A total of 72 Watermark Granular Matrix soil moisture sensors were installed between three PA and crop plants in each plot. Sensors were installed at 0.3-, 0.6-, and 0.9-m depths from the soil surface and data were collected every hour from the time of transplanting to biomass harvest of PA. Growth index, plant biomass, and average leaf area of three PA plants were determined at four separate removal timings throughout the growing season. The day before final PA biomass harvest, PA in soybean had the lowest total soil water (TSW) of 0.63 and 30.57 mm under CP and SDI, respectively. PA in fallow had the highest TSW of 290.9 and 298.60 mm under CP and SDI, respectively. These results indicate that ET of PA is highest in soybean and lowest in fallow situations. PA under SDI resulted in greater TSW as compared with PA under CP irrigation up until the R3 soybean growth stage. After the R3 growth stage, PA under SDI resulted in lower TSW as compared with PA under CP irrigation until the final PA biomass harvest.

Genetics of Dioecy in *Amaranthus tuberculatus* and *A. palmeri*: An Update. Jacob S. Montgomery*, Darci A. Giacomini, Patrick Tranel; University of Illinois, Urbana, IL (164)

With the frequency of herbicide-resistant weeds at an all-time high, production agriculture is feeling pressure to investigate weed management practices outside the field of chemical control. One such practice may be to manipulate sex ratios of dioecious weeds, such as waterhemp (*Amaranthus tuberculatus*) and Palmer amaranth (*A. palmeri*). For example, by converting all individuals of a population of these species to males, local extinction could occur. Before any gender-manipulation management practices may be developed, however, an understanding of the genetic basis of sex-determination is needed. To this end, a genome-wide association study was previously conducted on Palmer amaranth and waterhemp to identify genomic sequences linked to the male phenotype. This study produced molecular markers for maleness as well as a rough estimation of the size of the Y-chromosomal region in these two species. In the current study, these male molecular markers were aligned to male and female long-read genome assemblies of Palmer amaranth and waterhemp to identify Y-chromosomal regions in each species. In Palmer amaranth, we identified one region of interest that was approximately the size of our previous estimate. In waterhemp, we used an orthogonal set of genome sequences of male and female plants to produce a separate list of molecular markers for maleness. Using the two marker sets, we identified several contigs enriched for these markers. The combined length of these sequences is roughly equivalent to our previous estimate. These findings offer a list of candidate genes for sex-determination in each species that can be used in a gene drive system to manipulate sex ratios. Interestingly, comparison of these Y-regions identified few genes in common, supporting the previous hypothesis that waterhemp and Palmer amaranth evolved dioecy independently. However, an annotated gene that appeared in both Y-regions is being further investigated to determine if these two species evolved dioecy convergently.

Confirmation of Glyphosate Resistance in a Johnsongrass (*Sorghum halepense*) Biotype from Missouri. Sarah E. Dixon*, Reid Smeda; University of Missouri, Columbia, MO (165)

Paper withdrawn

Germination Patterns of California Weedy Rice (*Oryza sativa* f. *spontaneae* Rosh.) at Various Temperature and Water Potential Combinations Under Controlled Conditions. Liberty B. Galvin*, Mohsen B. Mesgaran, Kassim Al-Khatib; University of California, Davis, Davis, CA (166)

Weedy rice (*Oryza sativa* f. *spontanea* Rosh.) has recently become problematic in California rice cropping systems due to its conspecific features with cultivated varieties in tandem with a lack of herbicides available that will injure weedy rice without simultaneously injuring cultivated rice. Because of this, the stale seedbed methodology has been identified as a possible option for control of this pest. However, factors effecting the progress of early season phenology of weedy rice should be well understood before this strategy can be properly implemented. The objective of this experiment was to determine what range of temperatures and water potentials would promote or inhibit germination of California weedy rice accessions 1, 2, 3, 5 as well as 'M-206' rice (medium grain, median maturity) for comparison in a randomized block design. Seeds were primed with heat treatment to break dormancy and germinated at a range of temperatures from 10-35°C in 5°C increments, and a range of water potentials, from 0 to -0.8 MPa in -0.2 MPa increments. Results indicate that the base temperature for type 2 and 5 germination is 10°C; base temperature for types 1 and 3 is 15°C. At temperatures below 25°C accessions had variable responses to both water potential and temperature. At temperatures above 25°C, temperature appears to play a more significant role in germination compared with water potential. At 30°C all weedy rice accessions as well as M206 reached 50% germination within 4 days after seeding for most water potentials, inferring that 30°C may be optimal for germination of these accessions. Results from this experiment will be combined with previous emergence experiments and used to estimate when weedy rice seeds will appear in the field. This data will be used by researchers to optimize the timing of stale seedbed management strategies.

Determining the Origin of Glyphosate Resistant Amaranthus palmeri (*Palmer Amaranth*) in South America by Comparison of Extrachromosomal Circular DNA (eccDNA) EPSPS Replicon. Crystal D. Sparks*[1], Todd A. Gaines[1], Paul Neve[2], Anita Kuepper[3], Gancho Slavov[2], Martin Vila-Aiub[4], Alejandro Garcia[5], Aldo Merotto[6]; [1]Colorado State University, Fort Collins, CO, [2]Rothamsted Research, Harpenden, United Kingdom, [3]Bayer Cropscience, Frankfurt, Germany, [4]University of Buenos Aires, Buenos Aires, Argentina, [5]INIA Uruguay, Montevideo, Uruguay, [6]University of Rio Grande do Sul, Porto Alegre, Brazil (167)

The annual broadleaf weed Palmer amaranth (*Amaranthus palmeri)* is native to the Southwestern United States but has displayed a remarkable invasiveness into the Southeastern and Midwestern portions of the US, as well as portions of South America and Israel. This troublesome species has evolved resistance to multiple herbicide modes of action and can cause substantial yield loss in systems such as corn, soybean, and cotton. Palmer amaranth is dioecious and displays high fecundity, allowing for production of many offspring with high genetic diversity. The dispersal of high quantities of seed combined with questionable hygiene of agricultural equipment raises questions and concerns about the evolution and seed-mediated geographic dispersal of glyphosate resistance in *Amaranthus palmeri.* Previous work strongly suggests that increased EPSPS gene copy number is the main mechanism of glyphosate resistance in Palmer amaranth. More recent investigation into the EPSPS duplication in geographically distinct populations across the United

States identified the presence of an extra chromosomal circular segment of DNA (eccDNA) believed to harbor the high number of EPSPS repeats. Glyphosate resistance was officially reported in Brazil and Argentina in 2015, while resistance may have appeared in Uruguay around 2017. In this study the presence or absence of previously reported EPSPS eccDNA markers and total EPSPS copy number were compared across populations from the three South American countries. Brazil and Uruguay showed high similarity to glyphosate resistant populations across the United States, where a high copy number of EPSPS and the presence of eccDNA markers were observed. Populations from Argentina contained low copy number of EPSPS and the absence of EPSPS eccDNA markers, dissimilar to resistant populations in the US, Brazil, and Uruguay. These results suggest that there may have been a separate introduction of Palmer amaranth into Argentina, compared to Brazil and Uruguay.

Population Structure of Russian-thistle (*Salsola tragus* L.) in the Inland Pacific Northwest. Ian Burke, Drew J. Lyon, John F. Spring, Samuel R. Revolinski*; Washington State University, Pullman, WA (168)

Russian thistle (*Salsola tragus L.*) is a highly mobile problematic weed in the dryland wheat-fallow production regions of the inland Pacific Northwest. *Salsola tragus* is resistant to Group 2 ALS inhibitors and glyphosate, limiting herbicide-based management strategies. Our investigation aims to discern whether: 1. if discrete subpopulations exist within the inland Pacific Northwest; and 2. if such subpopulations do exist, does herbicide resistance status correspond to subpopulation. Knowledge of population structure may have important implications regarding the optimal scale of biologically informed management for the species on a regional basis. Seven individuals were collected from 21 sites across the inland Pacific Northwest dryland wheat production region. Each site was separated by ~40 km. A genotyping by sequencing strategy was used to generate single nucleotide polymorphisms (SNPs) by alignment of reads to the *Amaranthus hypochondriacus* L. reference genome version 2.1. Among the samples from the inland Pacific Northwest, using the package DAPC the optimal BIC was at one cluster suggesting no subpopulations are present. An Analysis of Molecular Variance (AMOVA) was performed and showed samples within location tended to be more related to each other on average than the rest of the population (rho = 0.062) and a permutation test of the AMOVA was significant (P = 0.01). Our results suggest that management must be strategized at the region level.

Interspecific Gene Flow Between *Sorghum bicolor* and *S. halepense* with and without Self-Pollen Competition. Cynthia Sias*, Blake L. Young, Daniel Hathcoat, George Hodnett, William Rooney, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (169)

The potential for gene flow between cultivated species and their weedy relatives poses agronomic and environmental concerns, particularly when there are opportunities for the transfer of adaptive or agronomic traits such as herbicide resistance into the weedy forms. One of the most widely cultivated crops in Texas, *Sorghum bicolor*, is a prime example of a crop that has a weedy relative, *S. halepense*, capable of exchanging genetic information. Previous findings have shown that the resulting triploid progenies typically collapse and only few of them develop into mature seed, whereas the tetraploids often turn into fully developed seeds. The objective of this experiment was to determine the impact of pollen competition on the frequency of hybridization between *S.*

halepense and *S. bicolor*. A total of 12 different cytoplasmic male sterile *S. bicolor* genotypes and respective male fertile lines were compared side-by-side on the level of hybridization with *S. halepense*, where *S. halepense* served as the pollinator parent. Results showed that pollen competition greatly reduced the rates of hybridization between *S. halepense* and *S. bicolor*. Further, there were differences in the frequency of hybridization among the *S. bicolor* genotypes evaluated. Results are helpful for developing appropriate gene flow mitigation strategies.

Evolution of Resistance to HPPD-inhibiting Herbicides in a Wild Radish (*Raphanus raphanistrum*) Population Via Enhanced Herbicide Metabolism. Huan Lu*[1], Qin Yu[2], Heping Han[2], Mechelle J. Owen[2], Stephen B. Powles[3]; [1]University of Western Australia, Crawley, Australia, [2]University of Western Australia, Perth, Australia, [3]University of Western Australia, Nedlands, Australia (170)

Paper withdrawn

The European Project IWMPRAISE: Integrated Weed Management in Olive Orchards of Spain. Veronica Pedraza[1], Irache Garnica[2], Juan A. Lezaun[2], Jose L. Gonzalez-Andujar*[3]; [1]CSIC, Cordoba, Spain, [2]INTIASA, Villaba, Spain, [3]Instituto de Agricultura Sostenible (CSIC), Cordoba, Spain (171)

IWMPRAISE is a five-year EU Horizon 2020 project on integrated weed management (IWM) with 38 partners in eight European countries. IWMPRAISE aims at supporting the adoption of IWM practices and demonstrate that its implementation can create cropping systems that are agronomically and environmentally more sustainable and more resilient without jeopardizing profitability or the steady supply of food, feed and biomaterials. IWMPRAISE develop, test and assess management strategies delivered across the most important cropping systems in Europe. Given the economic and agronomic importance of the olive crop in the Mediterranean region, Spain participates in the project within the group of perennial woody crops, in an attempt to improve the IWM systems carried out by farmers. Field trials will be conducted during 3 growing seasons (2018-2021) at two different locations: the south of Spain (Cañete de las Torres, Córdoba) and the north of Spain (Larraga, Navarra). The strategies tested are based on the most common weed management practices used by olive farmers in each area and the work aims at evaluating their influence on weeds, soil and crop yields and quality. Preliminary results for southern Spain showed cover crops establishment displayed greater weed diversity than chemical control and tillage management, as well as a higher weed density and biomass. Moreover, there were no effect on the olive yield and quality values and the existence of cover crops and the incorporation of olive pruning residues improved soil organic N contents. Therefore, these results provide positive indications for the use of this IWM strategy under southern Spain conditions and form a basis for further research on the optimization of this system. Further verification of these strategies on the agronomic and environmental effects are required during the 3-year study, in order to make better management decisions regarding the use of these techniques by farmers.

Identification of Goosegrass (*Eleusine indica*) Resistant to Dithiopyr and Dinitroaniline Herbicides. Joseph S. McElroy*[1], John M. Peppers[2], Nathan D. Hall[1], Elijah C. Russell[1], James Harris[1], Jinesh D. Patel[1]; [1]Auburn University, Auburn, AL, [2]Virginia Tech, Blacksburg, VA (172)

A goosegrass (Eleusine indica) population collected from a golf course putting green surround was evaluated for possible resistance to preemergence herbicides. Initial evaluation of field collected suspected resistant (R) and known susceptible (S) populations in hydroponics with dithiopyr or prodiamine at 0.1 uM revealed different phenotypic responses between R and S populations. Greenhouse preemergence rate titration screens of R and S populations indicates that S is controlled at a lower rate than R for both dithiopyr and prodiamine. Further evaluation of oryzalin and pendimethalin response confirmed R resistance to these herbicides. Sequencing of the alpha-tubulin gene revealed at Leu-136-Phe substitution which has been associated with mitotic inhibitor resistance in *Setaria viridis*. This is the first report of an amino acid substitution at Leu-136 being associated with resistance to dithiopyr.

Light Quality and Weed Seed Germination: What We Have Learnt and the Practical Application Potential. Albert T. Adjesiwor*, Andrew R. Kniss; University of Wyoming, Laramie, WY (173)

Most agronomic weeds produce prodigious numbers of very small light-sensitive seeds. These seeds accumulate in the seedbank where they will not germinate until they are exposed to light with a high ratio of red to far-red (high light quality). However, light sensitivity is influenced by species, seed dormancy and longevity. We quantified seed germination of kochia (*Bassia scoparia* (L.) A. J. Scott) (experiment 1) and common lambsquarters (*Chenopodium album* L.) (experiment 2) biotypes under red (660 nm), far-red (730), and darkness. Kochia seeds are short-lived and have little to no dormancy while common lambsquarters seeds are long-lived and have a high level of dormancy. Lettuce (*Lactuca sativa* L.), a far-red light-sensitive species was included as a check in both experiments for comparison. In experiment 1, the estimated maximum kochia germination was 63, 82, and 76% under the far-red, red, and darkness, respectively. Maximum lettuce germination was 22, 84, and 75% under the far-red, red, and darkness, respectively. Conversely, the maximum common lambsquarters germination (experiment 2) was 29, 78, and 33% under the far-red, red, and darkness, respectively. Kochia seeds appeared to be insensitive to the quantity of light but slightly sensitive to light quality. However, common lambsquarters seeds were sensitive to both light quality and quantity.

Risk Assessment and Tools for Monitoring Herbicide-Resistance Evolution in Weedy Sorghum. John Lindquist*[1], Melinda Yerka[2], Brigitte Tenhumberg[1], Amit J. Jhala[1], Rodrigo Werle[3]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nevada - Reno, Reno, NV, [3]University of Wisconsin-Madison, Madison, WI (174)

Johnsongrass is a troublesome perennial weed that is related to and capable of interbreeding with grain sorghum. Therefore, traits that improve sorghum may also become introgressed in Johnsongrass populations. The release of herbicide resistant grain sorghum represents a unique opportunity to identify the effects of a newly commercialized crop trait on weed populations and the trajectory of their evolution in US cropping systems. Our long-term goal is to identify gene flow mitigation strategies in sorghum that could support the use of genetically modified traits and minimize their potential impact on related weed populations. The objectives of this work were to quantify Johnsongrass demographic parameters necessary for predicting its long-term population dynamics in agroecosystems and to develop high-throughput molecular markers to monitor genetic diversity among weedy sorghum species and actual rates of gene flow from herbicide tolerant sorghum to its weedy relatives. Field experiments were conducted in Nebraska using two ALS-susceptible and two resistant populations to quantify Johnsongrass demographic parameters as influenced by herbicide application. Results were used to estimate Johnsongrass seedling and sprout survival, viable seed production, fresh rhizome and bud production and bud viability, seed and bud overwinter and within season survival, and the fraction of seeds and buds producing seedlings and sprouts. A stage-structured matrix population model was developed to predict the evolution of herbicide resistance in Johnsongrass due to gene flow from herbicide resistant sorghum. KASP (Kompetitive Allele-Specific PCR) assays were developed for rapid, inexpensive detection of all reported ALS target-site modifications. MIP's (Molecular Inversion Probes) targeting five sections of ALS and 35 genome-wide SSR's were developed for ultra-high-throughput confirmation of putative gene flow events detected by KASP. These will be used to support empirical validation of the risk-assessment model after release of ALS-resistant sorghum. This project can inform good stewardship practices for similar technologies in sorghum.

Multiple Resistance to ACCase, ALS and EPSPS Inhibiting Herbicides in the Genus *Lolium*.
Jose G. Vázquez Garcia*[1], Ricardo Alcántara-de la Cruz[2], Candelario Palma-Bautista[1], Hugo Enrique Cruz-Hipolito[1], Joel Torra[3], Antonia M. Rojano-Delgado[1], Rafael De Prado[1]; [1]University of Cordoba, Cordoba, Spain, [2]Universidade Federal de São Carlos, São Carlos, Brazil, [3]Universitat de Lleida, Lleida, Spain (175)

In Chile, there has been an alarming increase in the selection of populations of *Lolium* spp. (ryegrass) with multiple resistance to herbicides in recent years. In this study, we characterised the multiple resistance to glyphosate, diclofop-methyl, and iodosulfuron-methyl-sodium in resistant (R) populations of *Lolium* species collected in barley and wheat fields in Regions VIII and IX in Chile. Firstly, the R and susceptible (S, used as control) populations included in the study were confirmed to be *L. rigidum, L. perenne,* and *L. multiflorum* using Amplified fragment length polymorphism (AFLP) analysis. Whole-plant dose-response assays confirmed the resistances to glyphosate, diclofop, and iodosulfuron in the R populations, revealing variable and complex resistance profiles for each *Lolium* species. Enzyme activity assays of the target enzymes (5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), acetyl- CoA carboxylase (ACCase), and acetolactate synthase (ALS)) revealed that the multiple resistance of the three R *Lolium* spp. populations was provided by target site mechanisms, except the resistance to iodosulfuron in *L. perenne.* Sequencing of the target site genes revealed different combinations of accumulated mutations responsible for conferring herbicide resistance in each *Lolium* species. *Lolium multiflorum* presented the mutations Pro-106-Ser/Ala (EPSPS), Ile-2041-Asn + Asp-2078-Gly (ACCase), and Trp-574-Leu (ALS). *L. rigidum* had the mutations Pro-106-Ser (EPSPS), Ile-1781-Leu + Asp-2078-Gly (ACCase) and Pro-197-Ser/Gln + Trp-574-Leu (ALS). On the other hand, *L. perenne* showed only the Asp-2078-Gly (ACCase) mutation. Since the specific EPSPS activity of R *L. perenne* population was four times higher than its S counterpart, glyphosate resistance in this species was due to *EPSPS* gene amplification. The iodosulfuron resistance presumably involves non-target site mechanisms. These findings demonstrate that multiple resistance to EPSPS, ACCase, and ALS inhibitors in *L. rigidum* and *L. multiflorum* involved an accumulation of mutations in the target site genes, while in *L. perenne*, both target and non-target site resistance mechanisms were present.

Multiple Herbicide Resistance in *Parthenium hysterophorus* from Central America. Candelario Palma Bautista*[1], Jose G. Vázquez-García[1], Hugo Enrique Cruz-Hipolito[1], Guido Plaza[2], Verónica Hoyos[3], Joel Torra[4], Antonia M. Rojano-Delgado[1], Rafael De Prado[1]; [1]University of Cordoba, Cordoba, Spain, [2]Universidad Nacional de Colombia, Bogotá, Colombia, [3]Universidad del Magdalena, Santa Marta, Colombia, [4]Universitat de Lleida, Lleida, Spain (176)

The appearance of weeds with herbicide resistance in banana crops in the Dominican Republic causes a significant yield decrease. One *Parthenium hysterophorus* resistant (R) population collected in Monte Cristi banana region was compared to a susceptible (S) population harvested from organic banana orchards located in the Azua region. The resistance factors obtained in the dose-response assays showed a high resistance to glyphosate, flazasulfuron and fomesafen. They also showed a medium resistance to glufosinate and 2,4-D, as well as a natural tolerance to paraquat (RF=1.0). The I_{50} values (herbicide needed to reduce the enzyme activity to 50%) obtained in the EPSPS, ALS and GS activity studies with glyphosate, flazasulfuron and glufosinate, respectively, were greater in R than in S, indicating the existence of a possible target site resistance mechanism. The effect of fomesafen on the PPO enzyme was measured by the Protox IX levels, obtaining approximately 5 times more Protox IX in the S population than in the R population, while the resistance to 2,4-D in the R population was determined by the lower accumulation of ethylene in comparison to the S population. The studies carried out with ^{14}C-paraquat allow us to conclude that the lower absorption and translocation in both the R and S populations would explain the natural tolerance of *P. hysterophorus*. This is the first case of multiple resistance to herbicides with different mechanisms of action confirmed in *P. hysterophorus*.

Relationship Between Glyphosate Resistance and Root Fluorescence in Italian Ryegrass (*Lolium perenne* L. spp. *multiflorum*) Populations from Oregon. Andréia Kazumi Suzukawa*, Carol Mallory-Smith, Andrew G. Hulting, Caio A. Brunharo; Oregon State University, Corvallis, OR (177)

Oregon is one of the largest producers of annual and perennial ryegrass seed in the world. Italian ryegrass, the same species as annual ryegrass but with undesirable end-user traits, is considered a troublesome weed in these grass seeds crops especially due to management of herbicide resistant populations and gene flow between crop and weed. Because of the open pollination system of ryegrass species, the extent to which the perenniality traits exist in Italian ryegrass is largely unknown. A recent survey conducted in the Willamette Valley indicated widespread presence of multiple- and cross resistant Italian ryegrass populations. We hypothesized that frequency of glyphosate resistance in Italian ryegrass populations is not related to its perenniality, i.e. it is equally likely that annual- and perennial-descent Italian ryegrass evolved glyphosate resistance. Ten populations of Italian ryegrass collected in western Oregon were tested, of which five were putative glyphosate-resistant and five -susceptible, in addition to an annual and a perennial ryegrass cultivated varieties used as positive and negative controls, respectively. We initially conducted a root fluorescence test as a marker of perenniality, followed by a growout test to verify

the accuracy of the root fluorescence test. Seeds were germinated in filter paper, fluorescence visually assessed 7 days after seed imbibition, and seedlings identified and transplanted to pots for further evaluation of the leaf arrangement in the culm. Glyphosate was applied at a rate of 940 g ae ha^{-1} when plants were in the BBCH-32 growth stage. We conducted a chi-squared test with the expectation that an equal ratio of Italian ryegrass biotypes descended from annual and perennial cultivars exhibited glyphosate resistance. Fluorescence tests exhibited inconsistent results in comparison to the growout test, where the latter is standard in the grass seed industry. Approximately 95% of the weed biotypes assessed that exhibited glyphosate resistance descended from annual ryegrass, and from those annual ryegrass seedlings, the resistance to susceptible ratio was 1:1. We conclude that the glyphosate resistant populations of Italian ryegrass from Oregon tested predominantly exhibited annual ryegrass genealogy. Future studies will focus on the genetic background that correlate perenniality and glyphosate resistance.

***Chloris radiata* Resistant to EPSPS and ALS Inhibitors from Colombia.** Veronica Hoyos[1], Guido Plaza[2], Jose G. Vázquez García[3], Candelario Palma-Bautista[3], Antonia M. Rojano-Delgado[3], Rafael De Prado*[3]; [1]Universidad del Magdalena, Santa Marta, Colombia, [2]Universidad Nacional de Colombia, Bogotá, Colombia, [3]University of Cordoba, Cordoba, Spain (178)

Chloris radiata is an important weed in the central area of Colombia and has increased its abundance and distribution in rice crops, due to its difficult control. In previous research, glyphosate resistance was reported, and the objective of this study was to evaluate cross-resistance and multiple resistance to ALS inhibitor herbicides. A population of glyphosate resistant *C. radiata* (R) was applied with two ALS inhibitor herbicides, a commercial mixture of imazamox (33 g ai L^{-1}) + imazapyr (15 g ai L^{-1}) and bispyribac-sodium (400 g ai L^{-1}). Dose-response curve experiments were performed using the following doses: 0, 0.25X, 0.5X, 0.75X, 1X, 1.5X, 2X, 4X and 8X, where X corresponds to the recommended commercial dose for rice crops , 1.5 L ha^{-1} of imazamox + imazapyr and 125 g ha^{-1} of bispyribac-sodium; 16X and 24X as well were tested for this last herbicide. The application of herbicides occurred in the stage of 3-4 weed leaves and the variables analyzed were 50% survival plants (LD_{50}) and 50% reduction of fresh (fw) and dry weight (dw) of plants (GR_{50}). The susceptible (S) population was controlled at the field dose, while the R survived those doses. Dose response trials for the R population showed that the GR_{50} values of imazamox + imazapyr were 2094.78 (fw) and 1581.03 (dw) mL ha^{-1}, respectively, with a resistance factor (RF) 3.92 and 3.27 for the fw and dw parameters. For bispyribac-sodium, the GR_{50} of fresh and dry weight was 1419.79 and 1143.82 g ai ha^{-1}, respectively, and the RF was 25.13 and 22.78. Cross resistance to the herbicides imazamox + imazethapyr and bispyribac-sodium in the population of *C. radiata* previously reported as glyphosate resistant was confirmed.

Characterization of *Bromus* Species Using SSR Markers. José G. Vázquez García[1], Patricia Castro[2], Teresa Millan[2], Rafael De Prado*[2]; [1]University of Cordoba, Córdoba, Spain, [2]University of Cordoba, Cordoba, Spain (179)

The genus *Bromus* L. (Poaceae) comprises more than 160 species and includes annual and perennial grasses with different ploidy levels. This genus is widely distributed around the world and is characterized by its complex taxonomy. *Bromus* species are commonly found growing in olive and almond crops in Southern Spain. These species are extensively used as cover crops, but they can also be troublesome weeds for farmers. The most common method of weed control in perennial crops is by spraying herbicides. In order to apply the most effective herbicide treatment it is necessary to identify the species growing in the field. The identification of species relies on phenotypic characteristics. However, the taxonomy of *Bromus* species is very difficult to distinguish due to their high degree of morphological similarity. Molecular markers are a useful tool for plant characterization and could help differentiate *Bromus* species. In this study, we used SSR markers originally developed for *B. tectorum* to characterize different populations of *B. diandrus, B. tectorum, B. sterilis, B. rubens* and *B. madritensis*. These populations were previously morphologically characterized by a taxonomist. The SSR markers amplified in all populations demonstrating their transferability across the *Bromus* species. The markers were highly polymorphic and yielded unique alleles among the species. A total of 21 alleles were generated with an average of 7 alleles per loci. The number of common and unique alleles varied among the species. *B. sterilis, B. diandrus* and *B. madritensis* were the species with the highest number of common alleles, whereas *B. tectorum* and *B. rubens* had the highest number of unique alleles. Cluster analysis showed that the species could be grouped in different clades being distinguished from each other. These results confirm the results previously obtained by the morphological characterization and indicated that the SSR markers were useful to discriminate different species of *Bromus*. At the moment, we are testing if these population are tolerant to herbicides such as glyphosate, which is the most used for weed control in perennial crops in Spain.

Using Canopy Hyperspectral Reflectance Data to Distinguish Six Pigweeds. Reginald S. Fletcher*; Affiliation Not Specified, Greenville, MS (180)

Abstract not available

Management of Downy Brome (*Bromus tectorum* L.) in Fallow Systems with Indaziflam. Tara L. Burke*[1], Derek Appel[2], Rachel J. Zuger[3], Ian Burke[3]; [1]Washington State University, Albion, WA, [2]Washington State University, Davenport, WA, [3]Washington State University, Pullman, WA (181)

Downy brome (*Bromus tectorum* L.) is a difficult weed of various crops in the Pacific Northwest and elsewhere. Control of downy brome is often difficult to achieve as downy brome has evolved to avoid management inputs. Indaziflam, a cellulose biosynthesis inhibitor (WSSA group 29) of the alkyalzines chemical family, has been used for both monocot and dicot weed control in permanent crops since its initial registration in 2010. Despite increased use over time, there has been only a single instance of weed resistance to indaziflam. Thus, indaziflam is of interest for the control of problematic weeds, such as downy brome, in multiple systems. To this end, trials were implemented to examine long term effects of five indaziflam doses (5 to 40 g ai ha^{-1}) on downy brome populations in the dryland region of Washington. Trial initiation occurred in the spring of 2016 near Davenport, WA. Indaziflam was applied with and without pyroxsulam, a postemergence selective herbicide for the control of annual grasses. Control in the first year occurred mainly for indaziflam plus pyroxsulam (>80% at all rates by early summer). In the second year, a dose dependent relationship between rate and control was observed for both treatment types such that a higher application rate of indaziflam resulted in increased control. The highest rate of indaziflam alone was comparable to, or better than the highest mixture treatment rate early in the season

(>80% vs >70% for highest rate indaziflam alone vs mixture by early spring and >70% for both by mid spring). However, by late spring the highest rate of the mixture treatment provided the most control in the second year. Less downy brome biomass and thus more control was observed for the mixture treatments compared to both the nontreated and the indaziflam alone treatments. Thus, indaziflam alone and when mixed with pyroxsulam, was able controlled downy brome well into the second season after application and could be used to reduce or eliminate downy brome from the seed bank.

The International Weed Genomics Consortium: a Resource for Weed Genomics. Sarah Morran*[1], Paul Neve[2], Eric L. Patterson[3], Scott McElroy[4], Roland S. Beffa[5], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Rothamsted Research, Harpenden, United Kingdom, [3]Michigan State University, East Lansing, MI, [4]Auburn University, Auburn, AL, [5]Bayer AG, CropScience Division, Frankfurt, Germany (182)

The utilization of genomics to study weeds is expanding but remains limited by the lack of sequence resources for multiple weed species, and a lack of training among weed scientists to use genomics approaches. The potential application of genomic studies for weeds includes herbicide resistance, discovery of new herbicide targets, weed identification and diversity, the genetic basis of weedy traits, invasiveness, seed dormancy, allelopathy, biological control, and reproductive characters. Currently, close to ten weed species have a sequenced reference genome, in various stages of completeness. The International Weed Genomics Consortium (IWGC) has been established as a coordinated international effort in weed genomics and represents the community of scientists from academia and industry with interests in the genomics of weedy plant species. The vision of the IWGC is to 1) obtain high quality assembled reference genomes for the most important weed species worldwide; 2) to provide user-friendly genome analytical tools and user training through web-based databases and resources; and 3) to facilitate discussion and collaborations within this emerging field. The goal of the IWGC is to sequence the genomes of 10 weed species in 3 years, make the assemblies publicly available, and to train the weed science community in the use of genomics tools and databases. Participation from interested scientists is requested.

Genotyping *Echinochloa* for Species Identification and Resistance. Sarah Morran*, Todd A. Gaines; Colorado State University, Fort Collins, CO (183)

A challenge for growers worldwide is to respond to the continuing adaptation, invasion and spread of weeds in their cropping systems. The presence of multiple genomes in a weed can provide the plant with a higher level of genetic variation, providing a wider range of phenotypes across a wider range of environmental conditions. This, in turn, can affect the ability of the plant to be competitive in new and non-optimal environments. The *Echinochloa* genus contains multiple polyploid weed species, particularly *E.colona*, *E. crus-galli*, and *E. phyllopogon*, that are problematic in various cropping systems throughout the United States. Identification and subsequent management of these species has historically been difficult due to their similarity in morphological traits. The development of genotyping strategies such as Kompetitive Allele-Specific PCR (KASP) may provide reliable SNP genotyping solutions for identification. Sequence alignment of the Internal Transcribed Spacer (ITS)2 region of *E. colona* and *E crus-galli* identified two single nucleotide polymorphisms that were candidates for markers for KASP assays. These two SNPs were successfully used to reliably distinguish between the two species and thus may be used as a DNA-based species diagnostic tool. We aim to further investigate the potential for this approach to identify potential hybridization and movement of herbicide resistance between these species.

Characterization of F1 Hybrid Progenies Originating from Grain Sorghum (*Sorghum bicolor*) x Johnsongrass (*S. halepense*) Crosses. Nithya K. Subramanian*[1], Cynthia Sias[1], Usha Rani Pedireddi[1], Sara Ohadi[2], Daniel Hathcoat[1], George Hodnett[1], William Rooney[1], Muthukumar V. Bagavathiannan[1]; [1]Texas A&M University, College Station, TX, [2]University of California, Davis, Davis, CA (184)

Cultivated sorghum and its weedy relative johnsongrass have the potential to cross-pollinate and produce viable hybrids due to their genetic similarities. However, the phenotypic and growth characteristics of the hybrid progenies resulting from such crosses and their potential to persist in the environment are not well studied. The objective of this study was to determine growth and adaptive characteristics of F_1 hybrids obtained from crosses made with diverse male-sterile sorghum parents (female) and a johnsongrass biotype (pollen donor). These crosses were made under controlled conditions in 2017 and natural field conditions in 2018. The hybrid seeds originated from these crosses were planted in the greenhouse and ploidy status of the seedlings were determined using flow cytometry. A representative sample of up to 15 seedlings per ploidy type (haploid, triploid, tetraploid, pentaploid, and hexaploidy) per sorghum parental background were transplanted in to field nurseries, with at least 2 m distance between each seedling in all directions. The progenies obtained from each crossing experiment (2017, 2018) were established in separate field nurseries. The hybrid plants were characterized for a range of growth and reproductive traits, with some notable ones including plant height, stem width, number of tillers, biomass production, fertility, fecundity, among others. Preliminary results showed that, in general, the F_1 plants grew taller and produced more tillers and biomass than either parent. More detailed characterization of the progenies is currently underway. Findings from this study will help us determine the potential for long-term persistence of the hybrid progenies in nature.

Understanding Gene Flow from Grain Sorghum (Sorghum bicolor) to Johnsongrass (*S. halepense*). Nithya K. Subramanian*, Daniel Lavy, Cynthia Sias, George Hodnett, William Rooney, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (185)

Gene flow from cultivated sorghum to its weedy relative johnsongrass can pose ecological and environmental consequences, especially if novel agronomic (such as herbicide resistance) and adaptive traits (such as tolerance to abiotic and biotic stresses) are transferred to johnsongrass. However, little is known on the rate of gene flow from grain sorghum (male) to johnsongrass (female) under natural field conditions. A field experiment was conducted at Texas A&M University research facility near College Station, TX during summer 2019 to understand the rate of gene flow from Inzen® grain sorghum to johnsongrass. The Inzen® sorghum trait provides non-transgenic resistance to the acetolactate synthase (ALS)-inhibitor nicosulfuron, which served as a phenotypic marker to score gene flow in this experiment. The Inzen® sorghum was planted into a naturally occurring johnsongrass patch. A total of ten sampling units (2 m x 2 m) were marked within the experimental area with good johnsongrass density. Within each sampling unit, the johnsongrass panicles that exhibited flowering synchrony with sorghum were tagged. At seed maturity, the tagged johnsongrass panicles were harvested and bagged separately. The harvested seed were planted in greenhouse flats and the seedlings were sprayed with the label recommended rate (1X) of nicosulfuron (Accent®) at the 3 to 4 leaf stage. A known susceptible standard as well as a non-treated check were maintained for comparison. Survivors from the herbicide application were subjected to ploidy analysis using flow cytometry. Preliminary results confirmed the occurrence of gene flow from grain sorghum to johnsongrass. Molecular assays are being carried out to positively verify the hybrids based on the mutations specific to the Inzen® sorghum. Results provide novel insights into gene flow between sorghum and johnsongrass and will help develop suitable gene flow mitigation strategies.

Predictive Habitat Modeling for *Ventenata dubia* (Ventenata). Stacey N. Robbins*, Lisa J. Rew, Nicholas Fox; Montana State University, Bozeman, MT (186)

Ventenata (*Ventenata dubia*) is an invasive winter annual grass that invaded the Pacific Northwest (PNW) region of North America in the 1950s. In this region ventenata has decreased plant community diversity impacting other trophic levels, lowered forage production in pastures and rangelands and has the potential to increase soil erosion. Recent studies have improved our understanding of venenata's biology and ecological preferences within this region. However, the presence of ventenata is now documented to extend beyond the PNW region and into drier sagebrush steppe and rangelands of the intermountain west. Venenata was first recorded in 1995 in Montana, and in June 2019, it was listed as a priority 2a noxious weed, which requires eradication or containment of current existing populations. However, the actual distribution of ventenata is poorly documented in Montana. Research in Idaho indicates that the primary dispersal vector for the invasive is through the transport of ventenata infested hay that results in populations along roadsides that serves as a source for spread into surrounding natural areas. In this study we surveyed for venenata along roadsides in Gallatin County, MT, in order to provide a baseline dataset of the invasion extent. The species has recently been recorded in the county and known patches have been controlled with herbicide as part of an early detection rapid response (EDRR) approach. Roadside surveys utilizing GPS to record location, adjacent land use type, vegetative cover, percent cover of ventenata (trace <1%, low 1-15%, moderate 16-25%, high >25%) and community composition indicate that of 226 miles surveyed in the Summer of 2019, ventenata is only present along 2 miles of roadside (0.4% surveyed area). These variables were collated in a geographic information system with environmental variable of elevation, aspect and slope to better understand the ecological preferences within this area. Additionally, returning to sites treated as part of EDRR indicated that ventenata patches are shrinking or have been eliminated.

Waterhemp (*Amaranthus tuberculatus*) Seed Production and Seed Viability Following Injury from Sublethal Dicamba Dose. Mark L. Bernards*, Faith Duke, Allyson M. Rumler, Alexis L. Meadows, Brent S. Heaton; Western Illinois University, Macomb, IL (187)

Waterhemp is the most troublesome weed in many fields in the Midwestern U.S. because it has evolved resistance to many herbicides. Dicamba has been widely used to manage these resistant populations since 2017. However, many plants receive sublethal doses of dicamba because of shading by the crop canopy or other weeds at the time of application. Our objective was to measure the effect of sublethal doses of dicamba on waterhemp seed production and viability. A greenhouse trial was repeated in time. Waterhemp was treated at heights of 10 and 20 cm with increasing doses of dicamba, then allowed to recover until the plant died or produced seed. A field study was conducted where waterhemp plants were started in the greenhouse, treated at approximately 15 cm with increasing doses of dicamba, and then transplanted between soybean rows when soybean were at the V1 or V6 growth stage. After waterhemp senescence seed was harvested from each plant and weighed. Germination was evaluated by placing the seeds on moist filter paper in a sealed petri dish in a germination chamber set at 28 C and counting the number of germinated seeds after 2 weeks. A subsample of seeds that did not germinate were dissected, placed on a tetrazolium solution for 48 hrs to determine viability. In both greenhouse and field studies, waterhemp injury 28 days after treatment increased as dicamba dose increased. However, there was not a dicamba dose effect on seed production. In addition, in greenhouse studies seed germination and viability were not affected by dicamba dose. Waterhemp injured by sublethal doses of dicamba that is not then shaded out by the crop will produce seed that can contribute to the weed seed bank and the selection of plants less susceptible to dicamba.

WSSA Section 3. Turf and Ornamentals

Goosegrass (*Elusine indica*) Resistance to Mitotic Inhibiting Herbicides in Cool-Season Turfgrass. Katherine H. Diehl*[1], Matthew T. Elmore[1], James Brosnan[2], Sarah Boggess[2], Robert N. Trigiano[2]; [1]Rutgers University, New Brunswick, NJ, [2]University of Tennessee, Knoxville, TN (107)

Field and laboratory experiments were conducted to evaluate the response of three goosegrass populations on golf courses in New Jersey and Pennsylvania to microtubule-inhibiting herbicides. The golf course superintendent at each location reported poor goosegrass control following many consecutive years of microtubule-inhibiting herbicide use. Field research was conducted at these locations in 2017 and 2018 to evaluate the efficacy of dithiopyr, prodiamine, and oxadiazon for goosegrass control. The New Jersey golf course sites, East Brunswick and Manalapan, New Jersey, were perennial ryegrass (*Lolium perenne*) fairways. The Philadelphia Pennsylvania site was a golf course rough. Treatments consisted of single and sequential PRE applications of dithiopyr and prodiamine (applying a total of 0.56 to 0.84 kg dithiopyr ha^{-1} and 0.56 to 1.12 kg prodiamine ha^{-1}) compared to various oxadiazon programs (= 2.24 kg ha^{-1}). At the Manalapan location all dithiopyr and prodiamine treatments provided < 10% goosegrass control at 15 weeks after treatment compared to = 90% control for oxadiazon. Similar results were observed at the East Brunswick location. At the Philadelphia location, sequential dithiopyr applications provided 95% control, whereas both prodiamine programs and the single dithiopyr application resulted in < 20% control. Goosegrass plants were collected from dithiopyr-treated plots at these sites and grown in a greenhouse to flower and produce seed for further testing. Laboratory experiments were conducted to determine sensitivity of these three putative resistant goosegrass populations to dithiopyr and prodiamine compared to a known susceptible population. A bioassay to determine goosegrass seedling root response to dithiopyr and prodiamine at 0, 0.01, 0.05, 1.0, and 10.0 µM

was conducted using Murashige and Skoog (MS) media in Petri dishes. Roots of emerged plants were imaged and root length determined 21 days after planting using WinRhizo software. Root length data were subjected to non-linear regression in Prism. A lack of fit F-test (a=0.05) was conducted in Prism to determine if responses varied among populations. The a-tubulin (*TUA1*) gene from putative resistant populations were amplified, sequenced, and examined for a threonine to isoleucine substitution at position 239. Exposure to dithiopyr at 0.01 µM reduced root length of the susceptible and Pennsylvania populations to 0% of the non-treated, whereas the East Brunswick and Manalapan populations maintained root length values that were 85 and 100% of the non-treated control, respectively. Estimated GR_{50} values were 0.05 and 0.02 µM for the East Brunswick and Manalapan populations, respectively. Prodiamine at all rates completely inhibited root growth of all populations. The Thr-239-Ile target site mutation often responsible for resistance to mitotic-inhibiting herbicides was not detected in any of the populations. These results indicated that goosegrass populations from two different golf courses in New Jersey were resistant to dithiopyr, but the mechanism of resistance is unknown. Research to elucidate the mechanism of resistance is ongoing.

Growth Response of Southern Landscape Ornamentals to Low Rates of 2,4-D, Dicamba, and Glyphosate Particle Drift. Ryan D. Langemeier*, Steve Li, Katilyn J. Price, Frances B. Browne; Auburn University, Auburn, AL (108)

Growing use of synthetic auxin herbicides in row crops has increased the potential for off-target herbicide movement onto sensitive ornamental shrubs in nurseries and residential landscaping. Alabama's nursery and greenhouse industry contributes over $500 million to the state's economy. Due the high value of these crops', herbicide damage can impose significant costs to both commercial growers and homeowners. The objective of this study was to evaluate the sensitivity of three commonly grown southern landscape ornamentals to simulated drift of 2,4-D, dicamba, and glyphosate. The trial consisted of two locations with 6 replications at each location in Lee and Mobile counties. Crape Myrtle *(Lagerstroemia indica x fauriei* var. *Natchez)*, Japanese Holly *(Ilex crenata var. Compacta)*, and Azalea *(Rhododendron x* var. *Fashion)* were planted into pots in May, 2019 and sprayed in August, 2019. There were 6 replications of each species at each location. Herbicides were applied at 20%, 10% and 1% of field use rates for each product to simulate off target drift on ornamentals. Field use rates were 1065, 560, and 1540 g ai ha^{-1} for 2,4-D, dicamba, and glyphosate respectively. Growth indices ((height x width x width)/3) were recorded at immediately prior to spraying and 56 days after treatment (DAT). Visual ratings were recorded at 14, 28, and 56 DAT. At 28 DAT the 20% rate of 2,4-D caused the most severe injury to Japanese Holly at 13.8%. Azalea at 28 DAT exhibited the most severe damage for the 20% rate of dicamba, 10.0% and 13.3% for Lee county and Mobile counties respectively. Injury ratings 28 DAT for Crape Myrtle injury was the highest when treated with the 20% rate of 2,4-D at 8.3%. From 28 to 56 DAT injury ratings generally decreased more for 2,4-D relative to dicamba for Azalea and Japanese Holly, but this did not hold true for Crape Myrtle. For all three species glyphosate injury ratings generally dropped from 14 to 28 DAT, but increased or stayed the same from 28 to 56 DAT due to abnormal regrowth. Significant reductions in growth index, up to 20%, were recorded only for Japanese Holly. Observation of abnormal regrowth from all herbicides suggests only partial recovery is possible without pruning of damaged areas. Due to the importance of aesthetics in the ornamental industry, even minimal injury can reduce marketability.

Herbicide Phytotoxicity Influenced by Shade Timing and Density. Cameron Stephens*, Daniel Freund, James Kerns, Travis Gannon; North Carolina State University, Raleigh, NC (109)

Herbicide efficacy and phytotoxicity can be influenced by many environmental, biological, and edaphic factors. While there are numerous light-dependent herbicides across different modes of action, there are limited field studies evaluating the role of shade in herbicide phytotoxicity. Therefore, the objective of this research was to determine the influence of shade timing and shade density on turfgrass phytotoxicity following herbicide application. Shade structures (1.8m L x 1.8m W x 0.3m H) coupled with black shade cloth at 30, 60, and 90% shade density were constructed using a polyvinyl chloride frame. Field plots were exposed to each shade density at three shade timings including 2 days before herbicide application (2DB), 2 days after herbicide application (2DA), and two days before and after herbicide application (5DT). Single applications (rate) of sulfentrazone (0.9 L/ha), mesotrione (0.4 L/ha), and atrazine (4.8L/ha) were combined with an adjuvant (Induce; .25% by volume) and applied in 204 L/ha of water to 'Tifway 419' bermudagrass maintained at 1.3 cm and centipedegrass maintained at 5 cm. Phytotoxicity assessed visually and represented as percent values were collected 7, 14, and 21 DAT. Phytotoxicity on bermudagrass peaked at 7, 14, and 14 days after treatment (DAT) with atrazine (99%), mesotrione (86%) and sulfentrazone (86%), respectively. At 14 DAT, the main effect of shade timing significantly influenced phytotoxicity. Shade applied 2DB and 5DT resulted in the greatest phytotoxicity compared to the non-shaded sprayed controls. For centipedegrass, phytotoxicity peaked at 7 DAT with sulfentrazone (84%) and mesotrione (3%), and 14 DAT with atrazine (40%). Shade timing significantly influenced sulfentrazone phytotoxicity on centipedegrass on 7 and 14 DAT. Contrast to phytotoxicity on bermudagrass, 2DP shade timing resulted in the highest phytotoxicity whereas 5DT shade timing resulted in the lowest phytotoxicity with sulfentrazone. Turfgrass fully recovered by 21 DAT regardless of herbicide treatment on both bermudagrass and centipedegrass. Shade timing, and to a lesser extent shade density, may be an important parameter when applying herbicides to sensitive host crops.

Multi-State Research Evaluating Seedling Emergence and Herbicide Resistance Epidemic in Annual Bluegrass (*Poa annua* L.) in Managed Turfgrass Systems. Andrew W. Osburn*, Muthukumar V. Bagavathiannan, Becky Grubbs; Texas A&M University, College Station, TX (110)

Annual bluegrass (*Poa annua* L.) is a winter annual weed that can readily adapt to different environmental and management conditions due to high levels of genetic diversity. It is this rapid adaptability that makes annual bluegrass a troublesome weed in various turfgrass systems across the country, causing severe economic losses and greatly reducing the aesthetic value of carefully-managed systems. A team of scientists from 13 states (AL, FL, IN, GA, MS, NJ, NC, OR, PA, SC, TN, TX, and VA) are in collaboration to develop a thorough understanding of annual bluegrass within four primary turfgrass systems: golf courses, athletic fields, sod farms, and managed turfgrass lawns. This presentation provides an overview of two specific objectives from this work: (1) identify the prevalence of herbicide-resistant populations across the United States and (2) better understand seedling emergence patterns of annual bluegrass. To date, over 1000 unique annual bluegrass populations have been collected from each turfgrass system across five USDA plant hardiness zones, with a target of 2000 populations by the end of 2020. Each population consists of 20-25 individual plants which are tiller-propagated into flats and grown in a greenhouse. Preliminary herbicide screenings are being conducted on tillered populations after a 10-14 day acclimation period to evaluate plant response using the recommended label rate (1X). A total of twelve treatments (11 herbicides and a non-treated check) are being evaluated, which include trifloxysulfuron or foramsulfuron, pronamide, simazine, glyphosate, ethofumesate, paclobutrazol, mesotrione, diquat, glufosinate, prodiamine and indaziflam. Select biotypes are then advanced for subsequent dose-response assays. Additionally, seedling emergence patterns of annual bluegrass are being determined to help guide appropriate timing of management activities. Seedling emergence is monitored on a biweekly basis over two growing seasons between the fall of 2019 and the spring of 2021. Further, data pertaining to soil temperature, moisture, and rainfall are recorded to help explain seedling emergence patterns. Preliminary results of seedling emergence in two Texas locations, zone 4 and zone 5 plant hardiness zones, for the first observation cycle (fall 2019 to spring 2020) are presented.

How Can Weed Steamers Fit into a Landscape Weed Management Program? Cheryl Wilen[1], Guy G. Hernanadez*[2]; [1]University of California Division of Agriculture and Natural Resources, San Diego, CA, [2]University of California Division of Agriculture and Natural Resources, Lake Forest, CA (111)

The California Healthy Schools Act was established to 2000 to reduce pesticide exposure around schools and child care centers. There is currently strong public pressure to reduce the use of glyphosate in public areas. To address these concerns, University of California Cooperative Extension conducted research and demonstration trials using saturated steam for weed management as an alternative to herbicides near school sites. Saturated steam uses no chemicals thereby alleviating public perception of pesticide hazards, can be used when children are present, and no notification postings needed. Our primary objectives were to determine the efficacy of saturated steam as a management tool in landscaped areas, to evaluate the effect of steam on seed germination at different time durations, and to determine the time duration of control using saturated steam alone. We used a portable saturated steam generating machine SW700 (Weedtechnics, Terrey Hills, NSW, Australia) fitted with a 300mm closed head applicator or a 50mm open head applicator connected to a trigger operated applicator gun, both heads emitting 5l of water/min., in a park in Long Beach CA for one year. We also exposed black mustard (*Brassica nigra*) and common purslane (*Portulaca oleracea*) seeds to saturated steam for 0, 3, 30, and 60s. Results showed that most weeds were suppressed for approximately three weeks before retreatment was necessary. Some perennial species, such as Kikuyugrass (*Pennisetum clandestinum*), regrew within 1 – 2 weeks after treatment. Black mustard germination was reduced by 100% after 30s of steam exposure but 60s was needed to kill 100% of common purslane seeds. However, in practice, it would be infeasible to use the machine in to kill seeds on the soil surface.

Using Drone-collected Imagery to Map Invasive Pampasgrass (*Cortaderia selloana*) Across a Golf Course. Maggie Reiter*; University of California Cooperative Extension, Fresno, CA (112)

Pampasgrass (*Cortaderia selloana*) is a perennial grass and an invasive plant of open space areas. Colonization can affect naturalized areas of golf courses, where it alters native plant communities and contributes biomass to fire fuel risks. Mapping pampasgrass individuals across a golf course could be helpful to understand ecological dynamics at spatial scales, and could inform integrated pest management (IPM) planning for practitioners. Drones or unmanned aerial vehicles (UAVs) are useful for high-resolution mapping of large parcels and difficult-to-reach natural areas. The objective of this experiment was to develop a map and quantify pampasgrass individuals across a golf course. In December 2019, aerial imagery was collected with a DJI Mavic Air across a 200-acre golf course in central California. Images were mosaicked in Pix4D and individual pampasgrass plants were manually entered into a point layer in QGIS. This process resulted in a vegetation map of the entire golf course and a distribution map of over 300 pampasgrass individuals. This experiment demonstrated a systematic approach using drones to gather information about vegetation distribution on golf courses. Our methods could be employed by golf course managers as a strategy to design an effective IPM plan for eradication and identify priority areas for continued monitoring.

Efficacy of Organic Herbicides and Other Alternatives to Glyphosate in Urban Landscapes. Maggie Reiter*[1], Karey Windbiel-Rojas[2], John A. Roncoroni[3]; [1]University of California Cooperative Extension, Fresno, CA, [2]University of California Statewide IPM Program, Davis, CA, [3]University of California Division of Agriculture and Natural Resources, Napa, CA (113)

Recent concerns about public health risks of glyphosate have led to increased bans or restrictions in California cities, counties, and school districts. Landscape management clientele had a quickly-evolving need to reduce or eliminate glyphosate from their integrated pest management (IPM) programs. One option is to use alternative or organic herbicides for weed control, but research-based information on organic herbicides performance in urban landscape systems is limited. To generate new knowledge that supports urban landscape clientele, we conducted a series of field trials across microclimates to evaluate glyphosate alternatives and organic herbicides. Our objective was to compare "organically acceptable" and alternative herbicides to conventional standards like glyphosate. We evaluated 14 herbicides across 3 locations in central and northern California. Field sites included grassy and broadleaf weeds in mowed lawn areas. Overall, there were differences among herbicide treatments depending on microclimate, weed species, and time of year. Burnout (citric acid + clove oil) did not perform well in any experiment. Urban landscape practitioners need to understand tradeoffs associated with alternative or organic weed control strategies. Compared to standard glyphosate-containing landscape herbicides, organic herbicides may have different personal protective equipment (PPE) requirements, reapplication frequency, active ingredient loads, cost, and acute toxicity.

A Survey of Herbicide Resistance Issues in Nursery Crops, Christmas Trees and Landscape Plantings. Joe C. Neal*[1], Jeffrey Derr[2]; [1]North Carolina State University, Raleigh, NC, [2]Virginia Tech, Virginia Beach, VA (114)

Preemergence and postemergence herbicides are an important weed management tool for nursery and Christmas tree producers, as well as for those maintaining ornamentals in landscape beds. While herbicide resistance has been widely reported in most agronomic cropping systems, incidences and impacts of herbicide resistance in amenity horticulture crops and sites are not well documented. A survey was prepared for nursery crop and Christmas tree producers and landscapers on the issues of herbicide-resistant weeds and offsite movement of herbicides used to control herbicide-resistant weeds. A majority of respondents felt that herbicide-resistant weeds were a serious problem and had personally observed herbicide resistance on properties they maintain. Resistance to glyphosate accounted for 68% of the reported observations of resistance; 15% reported resistance to triazine herbicides. The most common species for which resistance was reported were *Conyza canadensis*, *Amaranthus* spp., and *Ambrosia* spp. However, other "resistant" species listed by respondents (such as dayflower, goldenrod and "some woody vine") suggested that some growers did not differentiate between evolved herbicide resistance and herbicide selectivity. Most reported their weed control costs had increased due to resistant weeds. Additionally, approximately 20% of respondents had their operation affected by drift of herbicides from nearby farm fields, with most reporting limited damage from spray or vapor drift, but a few reported over 50% of the crop damaged.

Weed Control in Container-grown Tree Seedlings Using Mulches and Pre-emerge Herbicides. Anthony L. Witcher*[1], Eugene K. Blythe[2]; [1]Tennessee State University, Mcminnville, TN, [2]Auburn University, Auburn, AL (115)

Seed propagation and seedling production in containers is a common practice for producing woody plant material for a range of applications including nursery stock liners and reforestation programs. Weed control is a significant issue in containerized woody crop seedlings since plants may remain in the container for up to a year and manually removing weeds is a time consuming and costly process due to the amount of labor required. The objective of this study was to evaluate the effects of mulch and pre-emergent herbicide applications on seedling growth and weed efficacy. In June, seedlings (128 cell tray) of dogwood (*Cornus kousa*) and yellow-poplar (*Liriodendron tulipifera*) were transplanted to 8.9 cm diameter containers filled with a pine bark substrate and treated (after 3 d) with a mulch (0.8 cm depth; perlite, cedar shavings, pine pellets, or charcoal) or pre-emergent herbicide (sprayable formulation – isoxaben, pendimethalin, prodiamine, and trifluralin; granular formulation – dimethenamid-P + pendimethalin, pendimethalin, trifluralin, and trifluralin + isoxaben). After 2.5 months, seedling height and root dry weight were recorded. Seeds of bittercress (*Cardamine hirsuta*) and crabgrass (*Digitaria sanguinalis*) were in separate sets of containers treated as stated above. Weed seed germination percentage and weed shoot fresh weight were recorded at 4 and 6 weeks after sowing, respectively. Data for each treatment were compared to a non-treated control and *P*-values for multiple comparisons were adjusted using the Holm-Simulated method. In dogwood, shoot height was similar for all treatments compared to the control while root dry weight was reduced for several herbicides including trifluralin (sprayable), pendimethalin (both formulations), dimethenamid-P + pendimethalin, and prodiamine. In yellow-poplar, shoot height and root dry weight were reduced with sprayable trifluralin but all other treatments were similar to the non-treated control. For bittercress weed efficacy, reduced germination percentage was observed for several herbicides while shoot fresh weight was reduced by over 85% for all treatments except perlite, cedar shavings, charcoal, trifluralin (sprayable), and pendimethalin (granular). For crabgrass, all treatments reduced germination rate and shoot fresh weight by at least 85% (compared to the non-treated control) except perlite, cedar shavings, charcoal, and isoxaben. We demonstrated several pre-emergent herbicides were safe and effective for use in seedling production of dogwood and yellow-poplar and pine pellets were the most effective mulch for controlling bittercress and crabgrass. Increased mulch depth may provide improved weed control and should be evaluated further.

Herbicide Longevity in Nursery Container Substrates. James Altland*; USDA-ARS, Wooster, OH (116)

Postemergence herbicides are rarely applied to container-grown nursery crops due to phytotoxicity concerns. As a result, preemergence herbicides are used exclusively and applied repeatedly throughout the growing season, often in 8 to 12 week intervals. Preemergence herbicide efficacy may decline over time, resulting in reduced weed control several weeks after application if weed seed density remains high. The objective of this research is to evaluate efficacy of preemergence herbicides, under various cultural and management scenarios, on creeping woodsorrel (*Oxalis corniculata* L.) and flexuous bittercress (*Cardamine flexuosa* With.) by applying weed seed from 0 to 10 weeks after herbicide application. Granular formulations of pendimethalin, prodiamine + isoxaben, oxyfluorfen + pendimethalin, and flumioxazin were applied at their maximum labeled rates to separate groups of containers every two weeks for ten weeks. After the herbicide application at 10 weeks, 40 seeds of creeping woodsorrel and flexuous bittercress each were applied to all containers. Containers were subjected to either 0%, 30%, or 50% shade. Another group of containers were subjected irrigation applied as a single application, or split into 2 or 3 applications throughout the day. Shade level had no effect on herbicide performance or weed establishment. Increasing irrigation frequency resulted in reduce herbicide performance and greater weed establishment. All herbicides provided effective control when seed were applied within 2 weeks of herbicide application. Herbicides containing oxyfluorfen or flumioxazin provided effective preemergence bittercress and creeping woodsorrel control when seed were applied up to 8 to 10 weeks after herbicide application. Other herbicide products resulted in reduced control as the time between herbicide and seed application increased.

The Safety of Conifers to Select Pyridine Herbicides. Mark A. Czarnota*; University of Georgia, Williamson, GA (117)

Pyridine herbicides have be used for broadleaf weed control in aquatics, Christmas tree, forestry, ornamentals, roadside, and turfgrass situations. In these production situations desirable conifers are often inadvertently exposed to these herbicides through foliage contact (direct contact or drift) or root uptake (soil leaching). Over the years, certain pyridine herbicides have caused catastrophic losses in tobacco, vegetables, fruit, and most recently in ornamentals. Information for historical pyridine herbicide damage was used to select conifer species and pyridine herbicides for the study. Historical data from aminocyclopyrachlor indicating activity on *Abies* species and 4 / 5 needle *Pinus* species, while other pyridine herbicides are labeled for use on certain conifers. To help determine the varied selectivity on *Abies*, *Pinus*, and *Psuedotsuga* conifer species, a study was designed to evaluate the effect of pyridine herbicides when applied over-the-top of one gallon seedlings of these conifer genera. The 2 to 3 needle pine species selected for the study included: Longleaf pine (*Pinus palustris*), Slash pine (*P. elliottii*), and Shortleaf pine (*P. echinate*). The 4 to 5 needle pine species selected included White pine (P. strobus), Southwestern white pine (*P.*

strobiformis), and Korean pine (*P. koraiens*); and the firs species included in the experiment were Canaan fir (*Abies balsamea var phanerolepis),* Balsa fir (Abies balsamea), Fraser fir (*Abies fraseri*), and Douglas fir (*Pseudotsuga menziesii*). At 17 weeks after treatment (WAT), no significant damage was noted with any of the selected species. Ratings will continue for 52 weeks, and a sequential application is planned for 32 WAT. Also, a repeat of the study is planned for 2020. It is hoped that these experiments will provide information on sensitivity of these selected conifers to pyridine herbicides. It is also anticipated that these experiments can help determine if the parentage of these conifers can predict the sensitivity of select pyridine herbicides on conifer species.

Post-Emergence Goosegrass (Eleusine indica) Control with SpeedZone and SpeedZone + Topramezone Mixtures. Daniel P. Tuck*, Matthew T. Elmore; Rutgers University, New Brunswick, NJ (118)

Field research was conducted from 2017 to 2019 in North Brunswick, NJ to evaluate the efficacy of Speedzone (2,4-D + mecoprop-p + dicamba + carfentrazone-ethyl at 860 + 270 + 80 + 28 g ha^{-1}, respectively) alone and tank-mixed with topramezone for post-emergence goosegrass (*Eleusine indica*) control. In 2017, treatments were initiated on 20 June to evaluate single and sequential Speedzone applications on a three or four wk interval. Fenoxaprop (140 g ha^{-1}) and topramezone (25 g ha^{-1}) applied twice four weeks apart were included as standards. In 2018, treatments were initiated on 11 July and consisted of single applications of Speedzone and Speedzone + topramezone (6 and 12 g ha^{-1}), compared to two sequential applications of Speedzone on a 30-d interval. In 2019, treatments were initiated on 24 July and consisted of single applications of Speedzone EW (2,4-D + mecoprop-p + dicamba + carfentrazone-ethyl at 860 + 270 + 80 + 28 g ha^{-1}, respectively), topramezone at 12 g ha^{-1}, Speedzone EW + topramezone (12 g ha^{-1}), and triclopyr (35 g ha^{-1}) + topramezone (12 g ha^{-1}). The site in 2017 was a fallow research field with a history of goosegrass. The site in 2018 and 2019 was a simulated golf course fairway consisting of perennial ryegrass (*Lolium perenne*) with a history of goosegrass. Goosegrass plants were at 3- to 5-tiller stage and cover was > 30% and when the experiments were initiated. Treatments were applied using a CO_2-powered single nozzle boom with a 410 L ha^{-1} water carrier through an AI9504EVS nozzle. Topramezone was applied with MSO at 0.5% v/v, except when tank mixed with Speedzone. Goosegrass control was evaluated visually on a 0 (no control) to 100 (complete control) percent scale relative to a non-treated control. In 2019, goosegrass bleaching was evaluated visually on a 0 (no bleaching) to 100 (complete bleaching) percent scale relative to a non-treated control. In 2017, sequential applications of Speedzone provided >80% goosegrass control, while single applications provided <20% control at 9 WAIT. Sequential applications of fenoxaprop and topramezone provided >99% control. In 2018, tank mixtures of Speedzone + topramezone provided greater control (>85%) than Speedzone alone (45 to 55%) at 4 WAIT. Sequential applications of Speedzone provided more control than single applications of Speedzone from 5 to 12 WAIT. In 2019, tank mixtures of topramezone + Speedzone EW and topramezone + triclopyr displayed less bleaching than topramezone alone; Speedzone EW + topramezone displayed no bleaching while topramezone + triclopyr caused minor bleaching. Goosegrass control was generally similar among all treatments for the duration of the 2019 experiment. These data indicate sequential applications of Speedzone and Speedzone EW can control tiller-stage goosegrass but single applications provide poor control. Tank mixing Speedzone with topramezone provided better goosegrass control than Speedzone alone and eliminated undesired bleaching caused by topramezone. Future research should investigate the efficacy of low Speedzone rates tank-mixed with topramezone for use in turfgrass species that are less tolerant of 2,4-D-based herbicide mixtures.

Zoysiagrass Response to Nonselective Herbicides is More Dependent on Heat Units Than Geography. Whitnee Askew*, Jordan M. Craft, Mike Goatley, Shawn Askew; Virginia Tech, Blacksburg, VA (119)

Zoysiagrass (*Zoysia* spp.) is a warm-season grass utilized primarily in lawns and golf courses because of its density, visual quality, drought and wear tolerance, and reduced requirements for water, nutrients, and mowing. Glyphosate and glufosinate are labeled for use in dormant zoysiagrass but turf specialists rarely recommend this practice for fear that zoysiagrass may not be "completely dormant." Concerns about partially-green zoysiagrass turf precluding the use of nonselective herbicides have not been characterized in scientific literature. Five trials were initiated in Blacksburg and Virginia Beach, VA and in Starkville, MS to evaluate zoysiagrass response to glyphosate applied at 700 g ai ha^{-1} and glufosinate applied at 1680 g ai ha^{-1} applied at four applications timings in the spring of 2018 and 2019. Growing degree-day at base 32 F (0 C, GDD_{32}) accumulation began on February 1, 2018 and 2019 for all sites and application timings were 200, 400, 600, and 800 GDD_{32}. A mixture of 'Zenith' and 'Companion' zoysiagrass (ZC Blacksburg) mown at 6.3 cm, a 'Meyer' zoysiagrass (M Blacksburg) mown at 1.2 cm, and a 'Zeon' zoysiagrass (Zeon Blacksburg) mown at 1.2 cm served as trial sites in Blacksburg, VA. A 'Meyer' zoysiagrass mown at 2 cm was evaluated in Starkville, MS and a 'Compadre' zoysiagrass mown at 6.3 cm was evaluated at Virginia Beach, VA. All experiments were arranged in randomized complete block design with four replications. Visually-estimated zoysiagrass injury data were collected biweekly and temporal trends were fit to the Gaussian function using Proc NLIN in SAS 9.4 for each experimental unit and resulting estimated parameters were subjected to ANOVA and means separated using Fisher's Protected LSD P = 0.05. The *c* parameter was used to calculate the number of days over a threshold of 30% injury (DOT_{30}) which was also subjected to ANOVA and means separation. The two 'Meyer' zoysiagrass locations mown at 1.2 to 2 cm had 20±13, 51±15, 132±35, and 218±32 green leaves dm^{-1} at 200, 400, 600, and 800 GDD_{32}, respectively. 'Zeon' zoysiagrass mown at 1.2 cm had 15±8, 48±17 175±27, and 265±35 green leaves dm^{-1} 200, 400, 600, and 800 GDD_{32}, respectively. CZ Blacksburg and Virginia Beach zoysiagrass mown at 6.3 cm had approximately 42% less leaves dm^{-1} at equivalent timings. Glyphosate applied at 200 GDD_{32} and 400 GDD_{32} did not injure zoysiagrass above the 30% threshold level at any location. Glufosinate applied at 400 GDD_{32} injured zoysiagrass over threshold level for 10 to 25 days at all locations. At 600 and 800 GDD_{32} timings, glufosinate caused maximum zoysiagrass injury of over 85% regardless of location while glyphosate injury maxima ranged from 20 to 70%. Glyphosate can safely be applied to zoysiagrass at 200 GDD_{32} regardless of growing regions between northern Mississippi and Virginia. The results indicate zoysiagrass injury increases when herbicides are applied later in the season when more green foliage is present regardless of growing region.

Effect of Submersion Time on Germination of Four Weed Species. Alisha Shiffer*[1], Anthony V. LeBude[2], Joe C. Neal[1], James Altland[3]; [1]North Carolina State University, Raleigh, NC, [2]North Carolina State University, Mills River, NC, [3]USDA-ARS, Wooster, OH (120)

In the southeast U.S., nursery crops producers use open ponds as source water for irrigating container grown plants. After irrigation and rain events, production tailwater is captured in these ponds and often reused for irrigation without filtration. Weed seeds produced from weeds in containers, roadsides, or vegetation hanging over roadways and ponds can be introduced in source water and potentially taken back into irrigation. Because ponds have large surface areas, it make take days or weeks before seeds matriculate toward pump intake areas and be reintroduced into production through irrigation. Whether or not they are still viable has not been studied widely in nursery production. Therefore this study investigated the submersion of four common weed species in pond water at four nurseries in eastern North Carolina, U.S. Seeds were submerged at 61 cm for 7, 14, 21, 30, 60, 90, 120, 180, and 360 days beginning 20 Nov 2019, then retrieved and germinated for 30 days. Controls for all species were stored at room temperature in darkness and a subset was chosen randomly at each submersion date for comparative germination. After 60 days submersion, seeds of all species still germinated, but at significantly lower rates than the controls. The experiment will be repeated beginning 20 March 2020, and 20 June 2020.

WSSA Section 8. Formulation, Adjuvant, and Application Technology

Efficacy and Economic Analysis of Light Activated Weed Seeking Spray Technology in Eastern Washington Fallow Systems. Lydia S. Fields*[1], Rachel J. Zuger[1], Derek Appel[2], Ian Burke[1]; [1]Washington State University, Pullman, WA, [2]Washington State University, Davenport, WA (151)

Light activated weed sensing spray technology has great potential in fallow systems in Eastern Washington. Winter wheat or spring wheat is grown in a two-year rotation with fallow to conserve soil moisture and improve wheat yield potential. Weed management during fallow is essential and can affect the overall success of a system by ensuring adequate soil moisture for subsequent wheat plantings. Weed sensing sprayers could increase overall system efficiency by reducing per hectare herbicide application rates, without sacrificing herbicide efficacy. The objective of the first study, with four trials repeated over two years was to evaluate the efficacy and efficiency of weed sensing vs. broadcast sprayers using different herbicide treatments in a single application. The objective of the second study, with two trials, was to evaluate the overall efficiency of weed sensing vs. broadcast sprayers for the entire fallow season with glyphosate applied at the same rate. Weed sensing sprayer applications were more economical compared to broadcast applications as long as less than 33% of the area was treated. Herbicide efficacy between weed sensing and broadcast applications for control of Russian thistle, Tumble pigweed and Common lambsquarters did not differ. In the second study, the total for all broadcast glyphosate applications was \$21.55 ha^{-1} (1030 g ai ha^{-1}) and the average total cost for weed sensing applications was \$14.25 ha^{-1} (3080 g ai ha^{-1}), generating a savings of \$7.30 ha^{-1}. Growers will save money and maintain efficacy of herbicide application using weed sensing spray technology in Washington fallow systems.

Evaluating Spray Nozzles at Lower Heights and Pressures for Circular Application.
Haosheng Lin*[1], Joseph Neal[2], Gary Roberson[2], Sierra Young[2], Ramon G. Leon[2]; [1]North Carolina State University, Cary, NC, [2]North Carolina State University, Raleigh, NC (152)

Weeds can cause significant economic loss in container nursery crop production. There are only limited numbers of Post herbicides available in nursery crop production and most of them were registered for directed spray. POST directed applications are generally not feasible due to high crop density and size. Even though preemergence herbicides can reduce the need for hand weeding dramatically, frequent hand weeding is needed to maintain weed-free nursery containers. Previous research reported that growers can spend up to $9880 per hectare on hand-weeding. According to the 2017 state of the nursery Industry survey, the limited availability and cost of labor were the number one concern of 68% of growers. Thus, research was conducted to design an automated sprayer system capable of making directed applications with low nozzle heights (<10 cm) to 8 to 15 cm radius containers. According to our theoretical calculations, in order to have a uniform distribution in a circular spray application, the volume per area from outer to inner radius should have a decreasing linear function. Thus, nozzles with an off-center pattern were evaluated for a uniform distribution under the circular application. Experiments were conducted to evaluate swath width, depth and estimated “capture volume” of thirteen off-center nozzles at low heights and pressures. Nozzle tips evaluated were TeeJet off-center flat spray tips (OC-01, OC-02, OC-03, OC-04), TeeJet underleaf banding spray tips (UB85-0075, UB85-01, UB85-015, UB85-02, UB85-03, UB85-04) and TeeJet air induction underleaf banding spray tips (AIUB8502, AIUB8503, AIUB8504). Nozzle heights were 5 and 10 cm, and operating pressures were 20 and 30 psi. Spray patterns, swath widths, and depths were measured, and spray volumes were captured. Upon evaluation, all AIUB nozzles could not be operated at such low pressures and were therefore omitted from further evaluations. Applications from UB and OC nozzles are designed to be sprayed at heights greater than 50 cm. Therefore, it was imperative to assess the spray distribution of the nozzles operated at low heights. Spray distribution was evaluated using a spray pattern test device with ten 20 and 24 cm long by 1.2 cm wide aluminum U-channels. Alternating 20 and 24 cm channels ensure the output of each channel could be kept separate from the adjacent channels. A recirculating water pump system provided steady pressure. The next study evaluated the nozzles at the same heights and pressures as in the previous study. All UB nozzles were tested at 5 cm height and 20, 30 psi. Additionally, UB85-0075, UB85-01, and UB85-015 nozzles were tested at 2.5 cm and 15 psi. All data values were converted into ml min^{-1} cm^{-2} and coefficients of variability (CV) were calculated. The UB85-0075, UB85-01, and UB85-015 nozzles had the lowest CV's of 25.1, 28.0, and 26.4%, respectively when sprayed at 2.5 cm and 15 psi. The C.V. values for UB nozzles are from 25 to 71%, whereas, C.V. values for OC nozzles are from 41 to 85%. R^2 values for UB nozzles from linear regression analysis for are from 0.56 to 0.94 and OC nozzles are = 0.2. Based on this study, the UB85 nozzles provide the best distributions when operated in a circular application system and hold the greatest promise for directed herbicide applications in container grown crops.

Soybean Response to Dicamba Tank Contamination, Particle Drift, and Vapor. Frances B. Browne*[1], Steve Li[1], Katilyn J. Price[1], Ryan D. Langemeier[1], Greg R. Kruger[2]; [1]Auburn University, Auburn, AL, [2]University of Nebraska-Lincoln, North Platte, NE (153)

Tank contamination, particle drift, and volatilization have been identified as primary sources of dicamba off-target movement. In order to investigate soybean response to different types of dicamba exposure, field studies were conducted in 2017, 2018, and 2019. Sprayer contamination experiments involved a replicated study in 2017 in addition to a sprayer survey in Alabama in 2019. The initial study compared four cleanout protocols in three commercial sprayers for dicamba residue removal. All cleanout protocols were repeated three times in the field. Hagie Upfront STS 10, John Deere 6700, and SprayCoupe 4660 sprayers with tank capacities of 3570 L, 1590 L, and 1580 L, respectively, were used to apply dicamba (Clarity) at 1.12 kg ae ha^{-1} with a carrier volume of 93.5 L ha^{-1}. One cleaning method was triple rinse with water and the remaining three included a first rinse of 3% v/v ammonium, third rinse of water and the second rinses were either glyphosate, Fimco, or Protank detergent at 5.11 kg ai, 0.90 kg, and 0.95 L per 378.5 L water, respectively. Samples were collected at each rinse and analyzed through HPLC with a detection limit of 0.5 ppm. Dicamba concentrations at the fourth rinse did not exceed 1.25 ppm regardless of sprayer or cleanout protocol. Furthermore, rinsates from the fourth rinse were applied to sensitive soybean and no yield response was observed. These data suggest triple rinse with water is sufficient for dicamba removal. In order to further test efficacy, 25 commercial sprayers were surveyed in 2019 for dicamba residue retention following triple rinse with water. Dicamba (Xtendimax) was applied at 560 g ae ha^{-1} in addition to a drift reduction agent (intact) at 0.5% v/v with a carrier volume of 140 L ha^{-1}. Rinsates collected at the fourth rinse did not exceed 0.2 ppm for 88% of the sprayers tested (22 sprayers). The remaining 3 sprayers had concentrations of 0.47 to 1 ppm. However, these concentrations are not likely to result in yield loss. In order to compare soybean response at early bloom to dicamba particle drift and vapor, field studies were conducted in Macon County, AL and Lincoln County, NE. Broadcast applications of dicamba at 0.03, 0.14, 0.70, 3.51, 14.04, 35.07, and 140.28 g ae ha^{-1} were used to simulate particle drift in 2017, 2018, and 2019. Vapor drift was simulated through plastic tunnels placed over two rows of soybean to concentrate vapor emitted from soil pans treated with dicamba at 0.56, 5.59, 56.42, 559.17, 5591.75, and 11183.51 g ae ha^{-1} in 2018 and 2019. Visual injury was recorded 7, 14, 21, and 28 days after treatment (DAT) in addition to yield at harvest. Soybean injury resulted from particle drift was more severe compared to vapor. Visual injury resulted from particle drift ranged from 3% to 100% across site-years. However, soybean visual injury resulted from vapor exposure did not exceed 55% regardless of dosage. The lowest dicamba rate of particle drift to result in soybean yield loss across all site-years was 1.4 g ae ha^{-1}. Alternatively, vapor emitted from the highest rate of dicamba tested at 11183.51 g ae ha^{-1} did not result in soybean yield loss relative to the nontreated control. Yield response resulted from particle drift was correlated to dosage applied. However, no such relationship was observed for yield and dicamba vapor. Soybean response to dicamba particle drift was more severe as compared to vapor. Dicamba tank contamination, particle drift, and vapor can all induce a plant response and mitigation will be needed to minimize off-target movement.

A Novel Fluorescent Compound to Measure Herbicide Physical Drift. Vijay Nandula*; USDA-ARS, Stoneville, MS (154)

Abstract not available

EnlistTM Herbicides with Colex-D Technology for On-Target Applications. David M. Simpson*; Corteva, Indianapolis, IN (155)

The Enlist® weed control system comprises three components: Enlist® traits, Enlist herbicides and Enlist® Ahead management system. Enlist E3® soybean and Enlist cotton varieties provide robust tolerance to 2,4-D choline, glufosinate and glyphosate. Enlist Duo® and Enlist One® herbicides with Colex-D® technology are designed to reduce the potential for off-target movement. By combining Enlist herbicides with specified nozzles, research trials have shown that driftable fines can be reduced by 90% while maintaining coarse to extremely coarse spray droplet. While 2,4-D DMA has low volatility potential, Enlist herbicides reduced the 2,4-D volatility by 88% on average compared to traditional 2,4-D DMA in four large field flux studies. Laboratory volatility studies confirmed that tank mixing glyphosate, glufosinate or ammonium sulfate with Enlist herbicides did not significantly increase 2,4-D volatility. Enlist Ahead management resource provides farmers, retailers and applicators with an array of tools to understand how to use Enlist herbicides for on-target applications. Since introduction in 2017, Enlist cotton acres have increased over 400% while number of inquiries concerning off target movement has not increased. Beginning in 2019, Enlist herbicides were used for weed control in Enlist E3 soybean with no inquiries concerning off-target movement. The most common factors related to off-target movement of Enlist herbicides are applications made when wind was blowing in direction of a susceptible crop in adjacent downwind field and applications made into a temperature inversion. Enlist herbicides with Colex-D technology are designed to ensure on target application when applied according to label guidelines. Keys to on-target application of Enlist herbicides are follow label directions, use nozzles and pressures specified on the label, only tank mix with qualified tank mix partners found at www.EnlistTankMix.com, clean sprayer before and after application, apply when wind speed is between 3 and 10 mph, do not apply in temperature inversion, and do not apply when wind is blowing towards a susceptible crops such as tomatoes, fruiting vegetables, cucurbits, grapes and cotton without the Enlist trait and tobacco. "®™Trademarks of Dow AgroSciences, DuPont, or Pioneer and their affiliated companies or respective owners. ENLIST E3® soybean technology is jointly developed by Dow AgroSciences LLC and MS Technologies LLC."

Introducing Four New Adjuvants from AgraSyst for Herbicide Use. Jim T. Daniel*[1], Scott Parrish[2]; [1]Daniel Ag Consulting, Keenesburg, CO, [2]AGRASYST, Spokane, WA (156)

AgraSyst Inc. developed two new unique nonionic surfactants. AgraSyst 90 ™ is a blend of several surfactants. It contains surfactants with high and low HBL numbers. To those, humectants were added and finally a cat ionic, tallow amine. Two trials were conducted in the Colorado State

University to determine the effects of each of these ingredients. Average percent control of KSHSC, CHEBE, HELAN, W.WHEAT, and D BEANS gradually increased with the addition of each component. Field trials were then conducted at ISU, SDSU, U of MN (Waseca), and CSU to compare the effects of AgraSyst 90 with widely used nonionic surfactant for weed control with lower rates of glyphosate. Across all trials, Agrasyst 90 with glyphosate provided control equal to or very slightly better than the standard. AGRA LOW-DRIFT 90 TM was developed by adding a drift retardant to Agrasyst 90. Greenhouse and University field trials showed similar efficacy results to Agrasyst 90. Droplets from an aerial application of 3 GPA were measured with a Droplet Scan showed DV 10 of 310 microns compared to 190 microns for a standard NIS. Coverage was 26% for Low Drift 90 and 17% for the standard NIS.

Herbicide Influence on Bradyrhizobia Growth. Joy Amajioyi[1], Sharon Clay*[2]; [1]South Dakota State University, Brookings, SD, [2]SDSU, Brookings, SD (157)

Bradyrhizobia are the nodule-forming, N-fixing bacteria in legumes. On farm field testing has shown that applying Bradyrhizobia as a foliar application at V4 or V5 of soybean growth has increased yield up to 5%. An application alone may not be economical, but if combined with another management operation, for example a herbicide application, this may be profitable. However, will the herbicide mixture be deleterious to bacterial growth? Inoculant was mixed with several soybean herbicides and the suggested adjuvants and surfactants. Solution optical density at 650 nm wavelength, as a surrogate for growth, was quantified after 5 d. Solutions with glyphosate, glyphosate + AMS, and dicamba alone had optical densities 50% or lower than the positive control. The surfactant, Duce, had lower optical density at low (0.075 ml L^{-1}) than high (0.75 ml L^{-1}) concentration. A field rate mixture of glyphosate + dicamba + AMS + surfactant had an optical density similar to the positive control. These data suggest that the inoculant may be mixed with some herbicide combinations and not be adversely impacted. However, testing prior to application would verify the impact to bacterial growth.

Impact of Carrier Volume Rate on Efficacy of PRE-Emergence Herbicides in Wisconsin Cropping Systems. Ryan P. DeWerff*, Maxwel Coura Oliveira, Sarah V. Striegel, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (158)

In the US north-central region, the use of pre-emergence (PRE) herbicides is becoming a standard practice for weed control in corn and soybeans. Environmental conditions often challenge farmers with timely PRE herbicide applications in the upper Midwest (e.g., planting often takes priority over spraying when conditions are adequate in the spring). Combining planting and spraying into a single operation could mitigate challenges and enable growers to early-plant and spray. One potential challenge of applying herbicides with a planter mounted spray system is the minimum carrier volume, at least 94 L ha^{-1}, required by many herbicide labels. High carrier volumes increase tractor/planter weight and may necessitate stopping planting operations more frequently to refill the tank. Field studies were established at Arlington (2018, 2019) and Janesville, WI (2018) to evaluate the impact of lowering carrier volumes on PRE herbicide residual weed control in both corn and soybean cropping systems. The studies consisted of three herbicide products applied at their recommended field rate (corn study = Resicore [4.1 L ha^{-1}], Acuron Flexi [5.3 L ha^{-1}] and Anthem Maxx [0.3 L ha^{-1}]; soybean study = Canopy DF [158 g ha^{-1}), Fierce [280 g ha^{-1}] and Verdict [0.36 L ha^{-1}]) sprayed at five carrier volume rates (23, 47, 94, 140 and 164 L ha^{-1}) replicated four times and organized in a RCBD. An untreated control treatment was also included for each study. The crops were planted following pre-plant tillage, a common practice in Wisconsin. Herbicide treatments were sprayed after planting with a Gator operated at 8 km h^{-1} and nozzles spaced at 76 cm (simulating planting conditions). Different combinations of nozzle and spray pressure were used to achieve the different carrier rate volumes tested herein. Visual control, weed biomass, and weed density were recorded approximately 42 days after treatment. Carrier volume rate did not influence weed control of either the corn or soybean studies over three site years ($P>0.05$). For soybean herbicides, differences in weed control were observed among site years ($P<0.001$) and herbicide selection ($P<0.05$). In corn, there was a significant site year by herbicide selection interaction ($P<0.001$) likely caused by poor weed control of Anthem Maxx (<30%) at Arlington in 2018. Weed species composition and density differed among locations and years. Although further research is needed to validate our findings, reduction in carrier volume for delivery of PRE herbicides could mitigate some of the challenges associated with combining planting and spraying into a single operation. (assuming product labels allow and weed-free seedbed at planting).

The Utility of a Planter Mounted Pulse Width Modulation Spray System. Ryan P. DeWerff*, Nicholas J. Arneson, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (159)

Planter mounted spray systems are most often utilized to apply PRE-emergence herbicides to bare soil; however, there are other potential uses (e.g. cover crop termination, burndown weed control). Combining planting and spraying into a single operation can mitigate potential weather challenges with timely herbicide application as well as reduce the number of trips across a given field. Historically, this type of system is retrofitted onto planters utilizing a ground driven pump or conventional rate controller for accurate herbicide application. The advent of pulse width modulation (PWM) technology offers operators more control over their application. Advantages of a PWM system include uniform pressure and droplet size over a wide range of travel speeds, the ability to adjust application volume on the go without changing speed or pressure, and individual nozzle control which can help prevent overlaps and double application. To investigate the potential use of PWM on a planter mounted sprayer, our research program installed a CapstanAG PinPoint II system on a 4-row JohnDeere vacuum planter with MaxEmergeXP row units. The rest of the spray system consisted of a CO_2 cannister with a regulator for pressure adjustment, a Wilger visual ball flow indicator manifold, and Wilger DR110-02 nozzle tips. TeeJet nozzle bodies were attached to brackets mounted on the rear of individual row units. Two preliminary studies were conducted in 2019 to improve operational knowledge and better understand the capabilities of the PWM plant-spray system: (1) winter wheat cover crop termination and (2) burndown combined with residual weed control. Adequate cover crop termination and weed control were observed in the studies, respectively. These studies will be replicated in 2020. After a year of experience, the following improvements to the setup were identified: improved nozzle body mounts for more flexible height adjustments and replacement of the CO_2 cannister with an electric air compressor for a regenerative and more cost-effective supply of pressure. An electric pump with a rate controller is a possible option for a future upgrade.

WSSA Section 10. Biocontrol of Weeds

Evaluation of Biofumigants in California Strawberry Nurseries. Nelly Guerra*; University of California, Davis, Davis, CA (188)

With increased restrictions on fumigant use and an uncertain future for the use of methyl bromide in California plant nurseries, as well as demand for plants using organic-compliant methods, alternatives to soil fumigants such as steam and biofumigants are needed. Nursery plant production has the highest possible phytosanitary standards and requires an integrated approach to control soilborne diseases and weeds in organic produced strawberry nursery plants in Northern California. From May to September 2019 our study focused on a high-elevated organic strawberry nursery located near Macdoel, California. The objective of this study was to compare the effects of steam, methyl bromide, anaerobic soil disinfestation (ASD), and Dominus, a biofumigant which contains allyl isothiocyanate. Data was recorded monthly on the number of runners and daughters produced by the strawberry plants, as well as weed emergence from the soil. The treatment that was most affective in decreasing weed seed viability was Dominus. The treatments that were the most affective in increasing daughter and runner growth was steam and ASD. This examination shows biofumigants can complement steam to control weeds and create higher strawberry yields, insuring a cost-effective organic fruit production.

WSSA Section 11. Physiology

Recurrent Selection with Fenoxaprop Decrease *Echinochloa crus-galli* (Barnyardgrass) Control by Quinclorac. Carlos Alberto Gonsiorkiewicz Rigon*[1], Luan Cutti[2], Guilherme Menegol Turra[2], Enrico Zilch Ferreira[2], Todd A. Gaines[1], Franck E. Dayan[1], Aldo Merotto Jr[2]; [1]Colorado State University, Fort Collins, CO, [2]Federal University of Rio Grande do Sul, Porto Alegre, Brazil (189)

The most used herbicides to control barnyardgrass in rice are ALS and ACCase inhibitors. The continuous use of these herbicides has resulted in the evolution of resistance due to mutations at the target enzyme and enhanced detoxification. The increasing of detoxification may result also in resistance to other herbicides from the same or different mechanism of action. The objective of this study was to evaluate the effect of recurrent selection of the low doses of fenoxaprop-p-ethyl, imazethapyr, and the mixture of both on multiple resistance evolution to quinclorac caused by metabolism in barnyardgrass. The biotype used was CAMAQ (susceptible to fenoxaprop and resistant to imazethapyr). The minimum doses for weed control by the herbicides fenoxaprop (FE) and imazethapyr (IMA) were determined individually and in a mixture (MIX). Plant selection experiments were then performed with the low doses of each individual herbicide and in the mixture. Surviving plants at maximum doses were multiplied for three selection cycles. Survival experiment to quinclorac was performed by applying 1 and 2 x field label rate of quinclorac (375 g ha^{-1}) in approximately 50 plants of each selected population of the third generation, i.e. in 3rd generation selected three times with fenoxaprop (G3FE), imazethapyr (G3IMA), mixture (G3MIX), and plants of 3rd generation unselected by any herbicide (G3UN) used as control. The chi-square test (?2) was applied to indicate the probability of rejecting the null hypothesis (no difference between the G3UN and plants of G3FE, G3, IMA, and G3MIX). A dose-response curve was carried out for quinclorac with malathion (P450 inhibitor) using the 3rd generation selected plants mentioned above and unselected plants as control. Malathion was applied two hours prior to quinclorac application. Plants survival after application of quinclorac (375 g ha^{-1}) was higher in the G3FE plants (58%) in comparison to G3UN (12.2%) with p-value <0.001. Similar results were obtained with 750 g ha^{-1} quinclorac (54% survived in G3FE and 14% in G3UN) with a p-value <0.001. The recurrent selection with IMA increased control with quinclorac reaching 100% control when applied at 375 g ha^{-1} (p <0.05) and 750 g ha-1 (p <0.05). The recurrent selection with MIX did not change plant survival to quinclorac. The GR_{50} of G3FE was 179 g ha^{-1}, a 7.3-fold change increase relative to G3UN (24 g ha^{-1}). Prior application of malathion decreased the GR_{50} of G3FE to 54 g ha^{-1} quinclorac, decreasing the resistance index from 7.3 to 2.2. Recurrent selection with fenoxaprop decreased control of barnyardgrass by quinclorac. This decreased control to quinclorac may be due to increased metabolism by P450 enzymes, given that malathion reduced the RI. The continuous use of fenoxaprop in low doses favors the evolution of cross-resistance to quinclorac.

The Physiological Basis of Differential Resistance to PPO-Inhibiting Herbicides Used Pre- and Post-Emergent. Abigail Barker*, Franck E. Dayan; Colorado State University, Fort Collins, CO (190)

Since the evolution of resistance to PPO-inhibiting herbicides there have been multiple observations that plants resistant to a post emergent application are still controlled by pre-emergent treatments, although in a pre-emergent dose response they still show a similar LD50 ratio to the post-emergent dose response. Resistance to PPO-inhibiting herbicides is further complicated by the presence of two isoforms of the PPO protein in plants, namely PPO1 implicated in chlorophyll synthesis and PPO2 implicated in heme synthesis. In the past the accepted paradigm was that inhibition of PPO1 was more important since there is more metabolic flux through that pathway in plants, but most resistance mutations are on the PPO2 protein. Analysis of the transcripts and protein levels of PPO1 and PPO2 in soybean have shown that younger plants express higher levels of PPO2, which does not explain the higher susceptibility of younger plants. Higher glutamate levels cause more damage from PPO-inhibiting herbicides, therefore if younger plants have higher glutamate levels it could explain higher activity of PPO inhibiting herbicides. Antioxidants have the opposite effect on PPO-inhibiting herbicides, where more activity decreases the toxicity of the herbicide. Younger plants may have less accumulation of antioxidant capacity which could also influence the higher activity of the herbicides.

Altered Target Site-Based Resistance to Mesosulfuron, an ALS Inhibitor, in Italian Ryegrass from Mississippi. Vijay Nandula*[1], Darci A. Giacomini[2], Jason A. Bond[3]; [1]USDA-ARS, Stoneville, MS, [2]University of Illinois, Urbana, IL, [3]Mississippi State University, Stoneville, MS (191)

Abstract not available

Defining the Locoweed-Fungal Endophyte Complex: A Common Garden Study Comparing Locoweed Stress Responses with and without its Fungal Endophyte. Barbara Keith*[1], Megan Hofland[1], Sarah Ward[2], David K. Weaver[1], Tracy M. Sterling[3]; [1]Montana State University, Bozeman, MT, [2]Colorado State University, Fort Collins, CO, [3]Affiliation Not Specified, Bozeman, MT (192)

Locoweeds (mostly *Astragalus* spp. and *Oxytropis* spp.) are legumes that contain swainsonine (SWA), an alkaloid that causes severe economic losses in the western U.S. through the livestock disease 'locoism'. The fungal endophytes, *Alternaria* spp. section *Undifilum*, synthesize SWA in locoweeds. In greenhouse studies, the locoweed-fungal endophyte complex appeared physiologically asymptomatic, unlike in tall fescue where its endophyte can improve stress tolerance and enhance plant growth. To explore the role of the fungal endophyte on the locoweed *Oxytropis sericea* under field conditions, we established a common garden study near Bozeman MT using plants germinated from seeds with *O. sericea* endophyte (E+) and without endophyte (E-) in the seed coat. We measured overwinter survival, gas exchange, flower and seed production, seed viability and germination rates, and volatile organic compound emissions. To determine if epigenetics play a role in plant response to the endophyte, we investigated the effect of previous endophyte exposure on the physiological responses of plants by establishing two generations of *O. sericea* seedlings with the fungal endophyte (E+) and released from the fungal endophyte (E-). Overwinter survival rate of the parental population established in 2013 showed no difference after 6 winters for E+ and E- plants. However, E- plants had a higher survival rate for the 1st and 2nd generation of plants released from the fungal endophyte as compared with E+ plants for the same generation after 4 winters and 2 winters, respectively. We detected no endophyte effect for gas exchange. The parental population E+ plants exhibited an increase in seed pods/stem over that of E- plants for four of the six years of measurements, but this increase was not seen in subsequent generations. Volatile organic compounds from 1st generation E+ and E- plants collected in the field during June when plants were flowering and again in August after seed shatter contained numerous plant defense compounds including several terpenes. These compounds were slightly elevated in E- plants compared to E+ plants both in June and August. Thus far in this common garden study, we have detected no consistent effects of the fungal endophyte on locoweed physiology or reproductive fitness.

Inhibitions of Goosegrass (*Eleusine indica* L. Gaertn.) and Soybean [*Glycine max* (L.) Merr.] Germination, Growth, and Development by Cover Crop Residues. Avat Shekoofa*[1], Larry

Steckel[1], Clay M. Perkins[1], Virginia Sykes[2]; [1]University of Tennessee, Jackson, TN, [2]University of Tennessee, Knoxville, TN (193)

Cover crops are often used to suppress weeds and to improve soil quality by reducing erosion. Despite numerous benefits of cover crops, the contributions of cover crop species through their allelopathic impacts to weed management is not clearly defined. Moreover, little is currently known about the actual allelopathic effects of cover crops on growth and development of the following row crop such as soybean. A series of laboratory experiments were conducted at the West Tennessee Research and Education Center (WTREC) in Jackson, TN during summer 2019 to study the allelopathic effects of cover crops extracts on germination, seedling growth and development of goosegrass and soybean. Extracts from above-ground biomass of seven cover-crop species (wheat, cereal rye, hairy vetch, wooly pod vetch, crimson clover, winter pea, and canola) from two different locations (East and Middle TN) were tested at 0 and 50 v/v on goosegrass and soybean seeds in different sets of experiment, under controlled environments at 25°C. Germination percentage, germination rate (number of germinated seeds per day), and root length of seedlings were affected by cover crop extracts from both locations. The 50 v/v extract treatment from canola and wooly pod vetch showed no allelopathic effects on goosegrass germination percentage and rate (East TN). Both cereal rye and crimson clover showed no significant impact on goosegrass germination rate and percentage (Middle TN). All cover crops' extract (both locations) significantly reduced seedling root length ($P< 0.01$). Among all seven tested cover crop species sampled from East TN, canola (23%), wooly pod vetch (22%), and cereal rye (21%) showed the greatest allelopathic effects on soybean germination percentage. All cover crops' extract from Middle TN except canola significantly reduced seedling root length ($P< 0.01$). Almost all cover crops' extract (50 v/v), from both locations, significantly reduced soybean germination rate. Results indicate that cover crop species will play an important role in reducing goosegrass seed germination and root length due to their release of allelochemicals. It is also important to know the cover crop species before planting soybean. Finally, the location and environment may change cover crops' allelopathic potential.

Identification of Candidate Genes on Wheat Group 5 Chromosomes Associated with Halauxifen-Methyl Tolerance. Olivia A. Obenland, Brendan V. Jamison, Dean E. Riechers*; University of Illinois, Urbana, IL (194)

Natural tolerance to synthetic auxin herbicides in hexaploid bread wheat is primarily due to rapid metabolic detoxification, but genes encoding synthetic auxin herbicide-detoxifying enzymes have yet to be identified. Herbicide safeners are commonly used to achieve or enhance herbicide tolerance in wheat by enhancing the expression and activity of herbicide-detoxifying enzymes. While safeners have been utilized to enhance herbicide selectivity in cereal crops for decades, detailed knowledge regarding the signaling mechanisms that induce expression of herbicide-detoxifying enzymes is limited. With the recent release of a wheat reference genome, we hypothesized that wheat alien substitution (with the S genome of *Aegilops searsii*) and aneuploid lines could be used to identify candidate genes that govern natural and safener-induced tolerance to halauxifen-methyl (HM). Seedlings with 1-2 leaves (Zadoks stages 11-12) were treated with two POST rates of HM alone, and the highest rate of HM was also applied with cloquintocet-mexyl (CM; a foliar wheat safener) in the greenhouse. This method allowed for identification of wheat chromosomes that possess genes endowing natural HM tolerance, but not safener-induced tolerance. For example, among 21 alien substitution lines only the group 5 lines displayed significant decreases in biomass relative following HM treatments alone, especially the 5A/5S and 5B/5S substitution lines, but all lines responded to CM. An RNAseq experiment comparing untreated and CM-treated leaf tissue identified over 100 CM-inducible genes, and among them were several UDP-dependent glycosyltransferases (uGTs) and cytochrome P450 monooxgenases (P450s) on group 5 chromosomes. Based on protein similarity, one of the P450s identified on wheat chromosome 5A may encode a homolog of CYP81A6 from rice, which governs tolerance to several herbicides. Identification of uGTs is also noteworthy because these enzymes are involved in HM detoxification reactions in wheat. Ongoing research is aimed at functionally validating these candidate genes in terms of tolerance to synthetic auxins and other wheat-selective POST herbicides.

Root System Architecture and Genes Associated with Allelopathy in Weedy Rice. Brooklyn C. Schumaker[1], Swati Shrestha[2], Shandrea D. Stallworth[2], Auriana P. Tucker[2], Te-Ming (Paul) Tseng*[2]; [1]Mississippi State University, Starkville, MS, [2]Mississippi State University, Mississippi State, MS (195)

Oryza sativa (rice) provides up to 50% of the dietary caloric supply for an estimated 520 million people worldwide. Increasing productivity of *Oryza sativa* production is paramount to meet the demand of a growing global population. The most significant yield constraint in *Oryza sativa* production is weed competition. Weeds are successful in the field in part because of their genetic diversity, allowing them to adapt and thrive in various environments. Weedy *Oryza sativa* is one of the most problematic *Oryza sativa* weeds, exhibiting characteristics that suggest vast germplasm of potential traits for cultivated *Oryza sativa* crop improvement. One such trait exhibited in weedy *Oryza sativa* is allelopathy. Allelopathy is defined as any detrimental effect by one plant on another through the production of chemical compounds that escape into the environment. Incorporation of allelopathic traits into cultivated *Oryza sativa* lines may improve growth habits and assist in overcoming yield losses due to weeds. The overall objective of this study is to evaluate the genetic diversity among selected weedy *Oryza sativa* accessions, cultivated *Oryza sativa* (CL163 and REX), and allelopathic *Oryza sativa* (RONDO, PI312777, PI338047), using 30 SSR markers. Nei's genetic diversity among weedy *Oryza sativa* (0.4) was found to be higher than cultivated *Oryza sativa* (0.24) but less than allelopathic *Oryza sativa* (0.56). Population structure and genetic relationship regarding allelopathic potential were evaluated. No distinction was observed between allelopathic and non- allelopathic weedy *Oryza sativa* accessions. Accession B2 was found to be genetically distinct than the other weedy *Oryza sativa* accessions and possessed high allelopathic potential. This information will be helpful for ongoing *Oryza sativa* breeding efforts.

Herbicide Physiology Online: A Multi-Institutional Course Spanning a Decade. Tracy M. Sterling*[1], William Dyer[2], Sarah Ward[3], Lynn Igegneri[4], Erin E. Burns[5], Fabian D. Menalled[2], Deana Namuth-Covert[6], Mithila Jugulam[7]; [1]Affiliation Not Specified, Bozeman, MT, [2]Montana

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To address reduced availability of herbicide physiology courses offered at land-grant universities, and based on the demand from graduate students and agency/industry personnel, weed science faculty from multiple institutions partnered to develop and co-teach a rigorous, online, three-credit graduate-level course. This award-winning team with diverse research, extension and teaching expertise in weed science developed 20 eLessons that remain freely available for public use at University of Nebraska's Plant & Soil Sciences eLibrary (https://passel2.unl.edu); nearly 4000 new users from over 250 countries accessed the eLessons in 2019. Since 2002, nine eLessons were published in peer-review journals, 11 translated into Spanish, and all utilized in three educational research articles. Over $200,000 in NSF, USDA and internal university sources helped to cover developmental and site maintenance costs for the eLessons which serve as a digital textbook. Combining the interactive eLessons with educational tools including seminal and current literature synthesis, quizzes, and web-based, asynchronous discussion boards, the faculty team developed an online course entitled PSPP 546 - Herbicide Physiology which is hosted at Montana State University. The course presents herbicide classification and modes of action, resistance mechanisms, and practical diagnosis of field situations. PSPP 546 was first offered in 2006, and has been taught eight times since. A total of 95 students have taken the course, with annual enrollment ranging from six to 16 students, including 49 MS and 29 PhD students from 11 U.S. Land-Grant Universities, one Canadian Research University, and 17 agency, industry and Extension professionals from across the U.S. Participation of multiple instructors with varied backgrounds has successfully complemented insights from students who are from multiple national and international regions with highly variable agricultural systems. Course content has been continually modified and updated in response to student feedback, while positive student evaluations indicate that the course is well-designed and serves the weed science community by providing a valuable, rigorous learning experience.

A Genetic Map for *Amaranthus tuberculatus*. Brent P. Murphy*, Darci A. Giacomini, Jacob S. Montgomery, Patrick Tranel; University of Illinois, Urbana, IL (197)

A high-quality genomic assembly is a critical resource for genetic studies within a species. The concentration of resources upon a small set of reference accessions is desirable. WUS is an ideal candidate reference accession for waterhemp (*Amaranthus tuberculatus*), a predominant driver weed within the Midwestern United States. WUS has a well-documented history of use as a sensitive population for dose response analysis, and has comparable vigor to wild waterhemp collections. Two plants of the WUS population were selected for sensitivity to tembotrione, an inhibitor of 4-hydroxyphenylpyruvate dioxygenase. Separate clones were intermated with each other and crossed with select HPPD-inhibitor-resistant plants. Shotgun whole genome sequence derived from these parent plants was aligned to the newly constructed trio-binned waterhemp genome, and high-quality variants identified. Mapping populations derived from the resistant-by-sensitive crosses were sequenced using double-digest restriction-associated DNA sequencing and used to anchor a genetic linkage map for waterhemp. Pseudo-F_2 populations derived from the sensitive-by-sensitive cross are being phenotyped for herbicide sensitivity, vigor and fecundity. The pseudo-F_2 population was submitted to the Germplasm Resource Information Network (GRIN) for distribution as a community resource.

EPSPS Gene Copy Number of Glyphosate-Resistant Common Waterhemp Biotypes from Eastern Nebraska Counties. Rachana A. Jhala*[1], Todd A. Gaines[2], Crystal D. Sparks[2], Stevan Knezevic[3], Amit J. Jhala[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]Colorado State University, Fort Collins, CO, [3]University of Nebraska-Lincoln, Concord, NE (198)

Glyphosate-resistant common waterhemp is the most troublesome and difficult to control weed in corn-soybean cropping systems in Nebraska. Dose response studies have confirmed presence of glyphosate-resistant waterhemp in at least seven eastern Nebraska counties. The *EPSPS* (5-enolpyruvylshikimate-3-phosphate synthase) gene amplification is a mechanism of glyphosate-resistant waterhemp. This increase in gene copy number results in overexpression of the EPSPS enzyme targeted by glyphosate, enabling resistant plants to produce sufficient enzyme to maintain shikimate pathway even in the presence of glyphosate. Understanding the genetic basis and mode of inheritance of glyphosate resistance is important for predicting evolutionary trajectory. The objective of this research was to determine *EPSPS* gene amplification in glyphosate-resistant common waterhemp biotypes from seven eastern Nebraska counties compared with a known glyphosate-susceptible biotype. Greenhouse and lab studies were conducted at University of Nebraska-Lincoln. Glyphosate-resistant common waterhemp seeds from seven eastern Nebraska counties and known glyphosate-susceptible common waterhemp biotype seeds were planted in plastic pots. When plants were 10 to 12 cm tall, glyphosate was applied at 2X rate (1,600 g ae ha^{-1}) with labeled adjuvants in a chamber track sprayer. Majority of plants survived and leaf samples were collected from 20 plants from different pots from each county (20 x 7 = 140) and glyphosate-susceptible biotype (20 x 1=20). Genomic DNA extraction was performed on the leaf tissue using Qiagen DNeasy plant mini kit. Samples were tested for *EPSPS* gene copy number relative to one-copy reference gene, *CPS* (carbamoylphosphate synthase) using a qPCR thermal cycler protocol. Copy number analysis revealed that *EPSPS* gene amplification is present in all seven eastern Nebraska counties. The biotypes from Antelope, Dodge, Fillmore, and Washington counties had relative *EPSPS* gene copy number ranging from 1.9 to 5.8. The biotypes from Lancaster, Seward, and Pawnee counties had an average relative *EPSPS* gene copy number from 2.1 to 11.8. The next step in this project is to investigate and characterize the inheritance and inter-generational stability of amplified *EPSPS* gene copies in pseudo-F2 and pseudo-F3 progeny.

WSSA Section 12. Soil and Environmental Aspects

Seasonal Fluctuations of 2,4-D and Dicamba Concentrations in Bulk Deposition Samples Collected Throughout Missouri in 2019. Eric Oseland*[1], Robert Lerch[2], Mandy Bish[1], Kevin W. Bradley[1]; [1]University of Missouri, Columbia, MO, [2]USDA-ARS, Columbia, MO (199)

Bulk deposition is the sum of wet (rainfall) and dry (sedimenting particles) deposition collected in ambient air. This method has been used previously as a passive sampling technique to determine atmospheric and air contamination of herbicides. The objectives of this research were to: 1) evaluate atmospheric contamination of dicamba using bulk deposition sampling in geographically distinct regions of Missouri, 2) determine if there is a seasonal fluctuation in atmospheric contamination levels of dicamba , and 3) determine if a correlation exists between atmospheric contamination of dicamba and adoption levels of dicamba-resistant (DR) soybean. Bulk deposition collectors were established near 12 University of Missouri weather stations located in different regions of the state. Collectors consisted of a 1 x 1 m galvanized sheet pan that sloped towards a center opening and drained into a 19-L glass carboy stationed in an enclosed cabinet directly beneath the pan. The sheet pans were secured to a wooden frame and were suspended 48 inches above the ground. Sampling began in late-April and continued weekly through early-September. On weeks when no rainfall occurred, 1.9 L distilled water was poured across the collection pan to collect any potential dry deposition particles. A 200 ml partition of each sample was separated for dicamba analysis. Dicamba residues present in each partitioned water sample were bound to an anion exchange column then eluted from the column using methanol and ammonia hydroxide. Samples were concentrated to dryness and resuspended in 0.5 ml of methanol to achieve a 400x concentration from the original sample to increase HPLC-UV sensitivity to <1 ug/L. A corresponding survey of soybean producers was performed to determine the percent adoption of DR soybean near each sampling location. The results indicate a relationship between cumulative dicamba concentrations detected across the sampling period and adoption level of dicamba-resistant soybean (R^2=0.87). Dicamba was detected in samples at least once during the growing season at all locations except at the Cook Station location which was used as a control since there was no DR soybean production in this region. The Albany location had the second lowest adoption of DR soybean (30%) and accumulated the second lowest levels of dicamba throughout the season (<1 ug/L). The highest concentrations of dicamba were detected at Charleston, Portageville, and Senath which are each located in the southeastern portion of the state where adoption of DR soybean was highest (>85%). Cumulative concentrations at these locations measured 73, 113, and 165 ug/L respectively. Dicamba concentrations throughout the season were <5 ug/L in each of the remaining 8 sampling locations outside of the southeastern portion of Missouri, where adoption of DR soybean ranged from 40-70%. Highest detection levels at most locations typically occurred during peak spray application periods (May-July) and decreased when herbicide applications become less frequent (August). The concentrations of dicamba detected in this research appear to correlate to the adoption of DR soybean and cotton in Missouri, and indicate that dicamba has the potential to accumulate in the atmosphere and deposit in rainfall. Additional research will focus on identifying any potential weather and environmental factors that are responsible for greater dicamba accumulations in the atmosphere.

Effects of Repeated Herbicide Applications on Soil Microbial Communities: an Analysis of Microbial Fitness. Katie Martin*[1], Brad Hanson[2]; [1]University of California, Davis, Davis, CA, [2]University of California, Davis, Winters, CA (200)

Soil microbes are a key component in humus production, carbon and nitrogen cycling, as well as pesticide degradation. However, not all microbes are created equal; different classes of microbes have different functions within the soil environment. In many perennial cropping systems, in-season weed control options are somewhat limited and many growers return regularly to the same cornerstone conventional or organic postemergence herbicides. But in doing so are the repeated applications of herbicide selecting for microbes that use these molecules as an energy source? It is well known that microbes play a key role in the degradation of pesticides in soil. It is lesser known how post emergence herbicide use history effects the microbial communities and degradation of these compounds in soil. In a two-way factorial experiment, microbial fitness was evaluated by applying three herbicides to soils with five different crop-herbicide histories. The herbicides used were glyphosate (49 ug ae/g soil), capric and caprylic acids (715 ug ai/g soil), and ammonium nonanoate (668 ug ai/g soil). Two field sites supplied the five soil histories challenged in this experiment – the orchard site had plots with no glyphosate applied within the last five years and also plots treated with three glyphosate applications per year for the last five years. The vineyard site had plots treated with only glyphosate, only organic herbicides or only cultivation for weed control for the past two years. Soil was collected from the top 10 cm in the replicated field plots and then combined; the composite bulk soil was sieved and air-dried before use in the lab experiment. Microcosms containing approximately 600 grams of each soil history were dosed with each herbicide and kept at standard laboratory conditions. Samples were collected from each microcosm prior to herbicide dosage and at 0, 1, 7, 14, 21, 30, 60, and 90 days after treatment. Total microbial activity and live and dead bacteria counts were measured at each time point. The data show the soil history of the orchard sites had no effect on bacterial counts or microbial activity; however, the soil history of the vineyard sites had an effect on these metrics. Results indicate that glyphosate and both organic herbicide treatments had an initial effect on the ratio of live to dead bacteria and total microbial activity but after approximately 90 days the counts and activity recovered with no clear differences between the synthetic or organic herbicides. Future testing will analyze the phospholipid-derived fatty acids in the soil to determine the ecological function of the microbes present.

Optimizing Chemical Analysis of Dicamba Residues from Polyurethane Foam (PUF) Samples. Shelby E. Lanz*, Tom Mueller; University of Tennessee, Knoxville, TN (201)

The three cornerstones for good trace analysis of pesticides are accuracy, precision and sensitivity. A variety of tools and methods are used to optimize the ability of researchers to find biologically relevant concentrations of components of interest in various matrixes. The recent deployment of dicamba tolerant crops and the resultant off target movement issues has necessitated the use of air samplers to collect dicamba samples under field and lab conditions. This report details our method validation and optimization to allow the use of PolyUrethane Foam (PUF) as a sampling media to collect dicamba and then later extract from the PUF and analyze using LC chromatography procedures. When neat solvents were used in concentration steps, dicamba movement within the lab equipment was minimal. When PUF extracts were fortified and then run through concentration steps, there appeared to be some dicamba movement and thus cross contamination of untreated, control samples. This cross contamination is well-known to many labs that have conducted dicamba research. Care should be taken to account for both the apparent low recovery of dicamba from actual PUF samples, which would understate true concentrations; and for cross carryover to some samples, which may overstate the true concentration (a false positive).

Role of Bonechar in Indaziflam Efficiency on Weed Control. Kassio F. Mendes*[1], Ivan F. Furtado[1], Kamila C. Mielke[1], Alessandro C. Lima[1], Larissa M. Mota[1], Rodrigo N. Sousa[2]; [1]Universidade Federal de Viçosa, Viçosa, Brazil, [2]ESALQ/USP, Piracicaba, Brazil (202)

The addition of carbonate material in the soil can affect the availability of herbicides applied in pre-emergence. However, the effect of cow bonechar amendment on the herbicide indaziflam is not yet known. The aim of this study was to evaluate the effect of cow bonechar on herbicidal activity of indaziflam in weed population in tropical soil. Cow bonechar was added homogeneously to top soil, at 1, 2, 5, 10, and 20 t ha^{-1}, in addition to treatment with unamended soil. At 21 days after indaziflam (75 g ha^{-1}) application, injury weed levels, weed species that emerged spontaneously were identified and the quantity of weeds present in each sampling unit were collected. The carbonaceous material increased the retention of water in the soil and favored weed infestation. In the highest doses of cow bonechar (5, 10, and 20 t ha^{-1}), weed dry matter was measured ~35 g m^{-2}, regardless of herbicide application or non-application. Only 1.4 t ha^{-1} of cow bonechar has already been enough to reduce 50% of the weed injury level. The largest weed infestations in the treatments were *Eleusine indica* (86%) and *Digitaria horizontalis* (14%), and the others were *Amaranthus* spp., *Raphanus raphanistrum*, *Galinsoga quadriradiata*, *Commelina benghalensis*, *Nicandra physaloides*, and *Sonchus oleraceus*. Cow bonechar used as fertilizer for plants, can that it be considered a source of phosphate and calcium, decreases indaziflam preemergence herbicidal activity in tropical soil.

Transport of ^{14}C-Mesotrione Through Soil Columns Under Different Physical-Chemical Properties. Rodrigo N. Sousa*[1], Kassio F. Mendes[2], Alessandro C. Lima[2], Kamila C. Mielke[2], Valdemar L. Tornisielo[3]; [1]ESALQ/USP, Piracicaba, Brazil, [2]Universidade Federal de Viçosa, Viçosa, Brazil, [3]CENA/USP, Piracicaba, Brazil (203)

Herbicide leaching is influenced by soil physical-chemical properties as well as the prevailing climatic conditions. However, little is known about leaching of mesotrione in the soil, especially in tropical regions like Brazil. The objective of this study is to evaluate the leaching of ^{14}C-mesotrione (cyclohexane-2-^{14}C-mesotrione) in seven tropical soil columns under laboratory conditions. These soils represented a wide range of properties with varying textures, cation exchange capacity (44 to 154 $mmol_c$ kg^{-1}), pH (6.0 to 7.7), organic carbon content (0.58 to 27.32 g kg^{-1}) and clay mineral contents (50 to 605 g kg^{-1}), which are typical of tropical soils. Mesotrione residues were observed across all soil column layers (0-30 cm) in all evaluated soils by simulating

200 mm of water for 48 h. Leaching of mesotrione ranged from low (up 15 cm) to very high (up 30 cm and leachate) in the tropical soils and may pose a potential groundwater contamination risk. In sand and loamy sand soil, the mesotrione was quantified in the leachate at all sampling times as above 80% of the amount initially applied. Thus, mesotrione application without the prior knowledge of the soil physical-chemical properties can result in inefficient weed control on field condition due to high leaching potentials.

WSSA Section 13. Integrated Weed Management

Rapid Detection of Herbicide-resistant Annual Ryegrass (*Lolium rigidum*). Martina Badano Perez*, Danica Goggin, Roberto Busi, Hugh J. Beckie; University of Western Australia, Crawley, Australia (204)

Overreliance on herbicides for weed control is conducive to the rapid evolution of herbicide resistance. Annual ryegrass (*Lolium rigidum*) is a species that is prone to develop resistance to a wide range of herbicide modes of action. The detection of herbicide-resistant weed populations in the field can provide valuable insight to crop growers to optimize their herbicide use. However, proactive herbicide resistance testing is seldom used by growers because it is costly, time consuming and requires a dedicated laboratory. Therefore, an inexpensive and rapid test was conceived to simplify the detection process. An agar-based test was developed that was able to detect ryegrass resistance to glyphosate, clethodim, trifluralin and pyroxasulfone within seven days, using seeds of well-characterized resistant and susceptible populations. The tests for trifluralin and clethodim resistance were then validated by comparing the survival rate of field populations screened by a traditional pot experiment and with the agar test. Herbicide stability in the agar was measured to assess the shelf-life of the test. There were no significant differences between the agar test and pot experiments in terms of plant survival, but trifluralin was lost from the agar within 5 d. The results of this study could help to develop a test kit to help crop growers to monitor the evolution and spread of resistant weeds on farm, but the test would need to be used on seed samples submitted to a research institution rather than sent out to growers.

Impacts of Winter Cover Crops on Weeds in Southwest Irrigated Agriculture. Prashasti Agarwal*, Erik A. Lehnhoff; New Mexico State University, Las Cruces, NM (205)

Winter cover crops (WCC) may facilitate weed management by inhibiting weed seed germination, seedling emergence and suppressing weed growth within cash crop. In Southern New Mexico, however, with scarce winter precipitation and limited irrigation water available, producing sufficient cover crop biomass for effective weed suppression while conserving water resources for subsequent cash crop growth is challenging. This study assessed the minimum water usage required to produce a cover crop with enough biomass so as to obtain weed management benefits during cash crop growth. Three WCC species, Barley *(Hordeum vulgare)*, Austrian winter peas *(Pisum sativum subsp. arvense)* and mustard *(Brassica juncea var. Caliente 199)*, grown singly and in a three-way mix, under three differential irrigation treatments were evaluated for their weed suppressive potential at two sites in southern New Mexico. The experimental design was a split-plot design, with irrigation treatments as main-plot factor and the WCC species as sub-plot factor. Sweet corn *(Zea mays)* was planted as cash crop approximately four weeks after WCC termination. Irrigation had no effect on WCC and weed biomass production in the WCC phase at either site. Following WCC termination and incorporation, weed seedling emergence counts in barley and the three way-mix treatments were 89% and 95% lower than in dry-fallow treatments, respectively. During the critical period for weed control, weed biomass was lower in all WCC treatments than the dry-fallow control treatment. At Leyendecker, for each of the treatments, the corn yield was consistently higher in conventionally managed, non-weedy sub-plots than in unsprayed weedy sub-plots, regardless of WCC treatment. Also, all cover crop treatments yielded as much as the fallow treatment, if not more. This suggests that WCC grown under minimal water conditions could provide some early season weed control in sweet corn, even though it was not consequently reflected in sweet corn yield.

Winter Wheat Variety, Planting Date, and Herbicide Selection: Effects on Rescuegrass (*Bromus catharticus*) Management. Hannah C. Lindell*[1], Misha R. Manuchehri[1], Todd A. Baughman[2], Emi Kimura[3], Brett F. Carver[1], Lane S. Newlin[1], Justin T. Childers[1]; [1]Oklahoma State University, Stillwater, OK, [2]Oklahoma State University, Ardmore, OK, [3]Texas A&M AgriLife, College Station, TX (206)

Rescuegrass (*Bromus catharticus*) is first of many winter annual weeds to emerge in Oklahoma winter wheat. Growers can successfully manage rescuegrass in Clearfield® and CoAXium® systems; however, control in non-herbicide tolerant wheat often is poor. To evaluate integrated management of rescuegrass, a study was conducted at Lahoma, Marshall, and Stillwater, Oklahoma and Burkburnett, Texas to assess planting date, wheat variety, and herbicide selection on rescuegrass control. Wheat was planted at an early and mid- timing where the early date represented the optimal time to sow wheat harvested for grain. Recently released varieties, Green Hammer and Showdown, were used. Both varieties offer high yield potential; however, Showdown brings low competitive ability while Green Hammer offers high competition with advantage in forage yield. Two commonly used herbicides, pyroxsulam at 18.4 g ai ha^{-1} and sulfosulfuron at 35.2 g ai ha^{-1}, were applied when rescuegrass was at the 2- to 3-leaf stage. At Lahoma, a delay in planting date increased percent visual weed control provided by the two herbicides. At Marshall, the same trend was observed; however, pyroxsulam controlled rescuegrass more than sulfosulfuron by 23%. Additionally, rescuegrass plants were counted for two 0.10 m^{-2} quadrats per plot. Rescuegrass counts at Marshall decreased by 13 plants per 0.10 m^{-2} from the early to mid-planting date. Overall, a delay in planting date did decrease rescuegrass populations while pyroxsulam and sulfosulfuron are two herbicide options for non-herbicide tolerant wheat that provided between 27 and 51% control in these studies.

Ecological and Economic Implications of Integrated Palmer Amaranth (*Amaranthus palmeri*) Management Strategies in Cotton. Rodger B. Farr*[1], Jason K. Norsworthy[1], Tom Barber[2], Grant L. Priess[1], Mason C. Castner[1]; [1]University of Arkansas, Fayetteville, AR, [2]University of Arkansas System Division of Agriculture, Lonoke, AR (207)

Herbicide-resistant weeds, such as Palmer amaranth, have resulted in a need to adopt a multifaceted approach to weed control that reduces selection for herbicide resistance. Previous research has suggested that cover crops, deep tillage, the use of residual herbicides along with postemergence herbicides, and establishing a zero-tolerance threshold for weeds can disrupt the emergence of weeds and reduce weed seedbank populations. To study how these tactics impact the soil seedbank over time, a long-term study was initiated near Marianna, AR during the fall of 2018. This study was arranged as a split, split, split-plot with zero-tolerance being the whole-plot factor, deep tillage the sub-plot factor, cover crops the sub-sub-plot factor and herbicide programs the sub-sub-sub-plot factor. Weed densities and emergence were measured in four-quarter meter squares per plot at 21, 42, and 63 days after the initial herbicide application and whole plot, inflorescence-producing weed counts were taken at harvest. Soil cores were taken before and after the season to quantify changes in soil seedbank over each growing season. Results from 2019 showed a 76% reduction in Palmer amaranth emergence due to deep tillage. Deep tillage and hand-weeding both significantly reduced inflorescence-producing Palmer amaranth densities at crop harvest by 75% and 63%, respectively. The dicamba in crop herbicide program resulted in a 6.7% yield reduction and 8.7% reduction in net return compared to the standard program. The interaction between hand-weeding and deep tillage was also significant for both yield and net profit. These findings from the first year of this long-term study suggest multiple factors reduced the amount of Palmer amaranth seed that will return to the seedbank. Knowledge concerning to what extent these factors interact in subsequent years will aid recommendations for managing this weed in cotton in the midsouthern U.S.

Efficacy of Cotton and Peanut Residual Herbicides in High Residue Cover Crop System. Katilyn J. Price*, Steve Li, Frances B. Browne, Ryan D. Langemeier; Auburn University, Auburn, AL (208)

As herbicide resistant weeds continue to emerge and spread, alternative non-chemical control methods integrated into current control programs need to be evaluated. Few studies have been conducted to determine the effectiveness of residual herbicides sprayed onto cover crop residues compared to conventionally tilled systems. The overall objective of this trial was to determine if residual herbicides reach the soil surface providing benefits in a system utilizing high residue cover crop by measuring percentage of weed control, weed population counts, the length of weed control and weed biomass compared to conventionally tilled system. Field trials were conducted in Henry and Macon County in Alabama in 2019. Peanut treatments included; acetochlor 1,260, flumioxazin 107, diclosulam 26, *S*-metolachlor 1,700 g ha^{-1}, conventionally tilled non-treated check (NTC) and high residue NTC. Cotton treatments included; fluridone 168, acetochlor 1,260, fomesafen 280, fluometuron 1,680 g ha^{-1}, conventionally tilled NTC and high residue NTC. All treatments were applied with backpack sprayer the day of planting at 187 L ha^{-1}. Overall, total weed biomass in peanut plots with high residue cover and soi residual herbicides had significantly reduced weed biomass of 34%-89% compared to conventionally tilled NTC. Flumioxazin and diclosulam with high residue had the highest amount of weed biomass reductions of 89% and 82% respectively, compared to the conventionally tilled NTC in peanut. In cotton, all treatments including high residue NTC had significantly reduced weed biomass from 45-70% reductions compared to conventionally tilled NTC in Henry County. However, in Macon County, no herbicide treatment in combination with high residue or in conventionally tilled plots were significantly reduced from the conventionally tilled NTC in cotton. Overall, the combination of residual herbicides with a high cover crop residue provided more effective weed control overall compared to the conventionally tilled NTC meaning some residual herbicides are reaching the soil surface.

Impact of Harvest-time and Post-harvest Seedbank Management Tactics for Italian Ryegrass (*Lolium multiflorum*) in South-Central US Wheat Production. Aniruddha Maity*[1], Blake L. Young[1], Lauren M. Lazaro[2], Nicholas Korres[3], Jason K. Norsworthy[4], Muthukumar V. Bagavathiannan[1]; [1]Texas A&M University, College Station, TX, [2]Louisiana State University AgCenter, Baton Rouge, LA, [3]USDA-ARS, Urbana, IL, [4]University of Arkansas, Fayetteville, AR (209)

Italian ryegrass is a major weed problem in wheat production and other winter crops in the south-central United States (US). In addition to the high genetic diversity leading to wide adaptability, multiple herbicide-resistance, high fecundity, and extreme shattering tendency of Italian ryegrass make its management difficult under field conditions. Recent intervention through harvest weed seed control (HWSC) tactics developed in Australia, another country where ryegrass is the major weed problem in wheat production, promises a great potential to reduce ryegrass seedbank inputs and subsequent field infestations. A four-year study (2016-2019) was conducted in split-plot design, comprising of three main-plot treatments, (1) no HWSC + disk immediately after harvest, (2) narrow-windrow burning + disk immediately after harvest, and (3) narrow-windrow burning + disk one month after harvest; and two sub-plot treatments, (1) Pendimethalin (Prowl H_2O® @2242 g/ha) DPRE after wheat spiking, approximately 5 days after planting and (2) Flufenacet + Metribuzin (Axiom® DF @560 g/ha) + Pyroxasulfone (Zidua® WG @105 g/ha) EPOST at 1-2 leaf stage fb Pinoxaden (Axial PRO @1121 g/ha) in spring. These long-term experiments were established in College Station, TX and Newport, AR. At the end of experiment, narrow-windrow burning alone was significantly better than no HWSC, and a combination of HWSC and the herbicide program #2 was the most effective treatment in controlling ryegrass infestations. In these plots, final ryegrass densities during wheat harvest were close to 0 plants/m^2. The combination of a standard practice (no HWSC) and herbicide program #1 led to an increase in ryegrass infestation in the field (58 plants/m^2). Further, similar trends were also observed with seedling emergence (58.4 seedlings/m^2 in plots with no HWSC and herbicide program #1; 0.8 seedlings/m^2 with HWSC and herbicide program #2). Findings will be useful for developing an improved ryegrass management strategy in the south-central US.

Weed-Microbial Competition for Nitrogen in Soils Amended with Carbon: A New Soil Modification Tool for Weed Management? Maria A. Gannett*; Cornell University, Ithaca, NY (210)

Broad use of herbicides has created a strong selection pressure on weed communities and a subsequent increase in herbicide resistant weeds, creating a need for more non-herbicide based weed management tools. One potential method of weed control is through managing soil nitrogen availability since many agricultural weeds grow well in high nitrogen environments. It is hypothesized that nitrogen is immobilized and made temporarily unavailable to plants through soil carbon additions, which stimulate soil microbial growth. We predicted that many agricultural weeds would have reduced growth when nitrogen was immobilized this way. We added sawdust and sugar as a carbon source to soil in pots buried in a field and measured soil properties and weed biomass. Microbial biomass in carbon amended pots was significantly greater than in unamended pots. Additionally, there was less nitrate leached through the soil column into resin bags in the carbon amended pots, providing supporting evidence that more nitrogen was immobilized in those pots. Weed biomass for three of the eight weed species grown in the carbon amended pots was significantly less than in the unamended pots after 11 weeks of growth: *Amaranthus powellii*, *Amaranthus rudis*, and *Chenopodium album*. These species are known to grow well in high nitrogen environments. This experiment supports our objective of understanding how carbon amendments could be developed into an alternative weed management tool.

The Search for Herbicidal Natural Products from the Plants of Hawai'i. Joey Ooka*, Sherry-Ann Hara, Daniel K. Owens; University of Hawaii, Manoa, Honolulu, HI (211)

There is a growing interest in alternatives to commercial herbicides and increasing enthusiasm for organic farming practices. This is particularly true in Hawai'i where the protection of the land, water and its residents are of the highest concern. Allelopathic plants are defined as those that can produce their own natural herbicides to compete against other plants for desired resources such as nutrients and sunlight. We are establishing the allelopathic profiles of a variety of plants found in Hawai'i to identify and investigate any compounds with weed killing activity as potential new herbicide leads. Non-Native species are included within the study, as these plants are often undesired by conservationists who wish to restore Hawai'i's watershed back to its native state. In addition, there are still many details yet unknown about the interaction between invasive plant species and our native ecosystems. Strawberry guava (Psidium cattleianum) is one of the most widespread invasive species in Hawai'i and has been proposed to use allelopathy as part of its invasive strategy. Much of our initial research has focused on examining this allelopathic activity and identifying potential herbicidal compounds from this species. Additionally, we intend to examine the molecular target sites of any newly discovered compounds, to search for compounds with novel herbicidal modes of action to aid in combatting evolved herbicide resistance.

Population Dynamics of Common Waterhemp (*Amaranthus rudis*) Under Short-term Versus Diversified Cropping Systems, a Matrix Modeling Approach. Matt Liebman, Huong Nguyen*; Iowa State University, Ames, IA (212)

Abstract not available

Evaluation of *PtxD*-Phosphite as a Weed Control System in Cotton. Shilpa Singh*, Devendra Pandeya, Keerti Rathore, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (213)

Herbicide-resistant weeds have emerged as a serious problem in different cropping systems, specifically cotton-based systems. Development and adoption of new strategies and approaches is a prime need. Phosphorus (P) is an essential macronutrient required by the plants for normal growth and development. Plants can only metabolize P in its orthophosphate (Pi) form, but unable to utilize the phosphite (Phi) form. A transgenic variety of cotton with the bacterial *phosphite dehydrogenase* (*ptxD*) gene has the ability to convert phosphite (Phi) into orthophosphate (Pi), whereas weeds lack this ability and hence can be negatively impacted by Phi application. In 2019, a series of greenhouse studies were conducted to understand the effects of Phi and Pi application on cotton (*ptxD* and non-*ptxD* varieties) and weeds [Palmer amaranth (*Amaranthus palmeri*) and johnsongrass (*Sorghum halepense*)] in two soil types: low P [10 parts per million (ppm)] and normal P (50 ppm). The experiments were conducted in a randomized complete block design with three replications (four plants per replication). Initial tests were conducted with Phi and Pi rates ranging from 0 to 64X (1X=50 ppm). Subsequent experiments were conducted at four doses, i.e., 0, 64, 128, and 256X (1X= 5000 ppm) of Phi and Pi each With respect to soil applications, 95 and 80% control was observed on Palmer amaranth and johnsongrass, respectively in 10P soil, at the highest rate (256X) of Phi tested, whereas in the 50P soil the same were 80 and 75%. In general, at 7 days after treatment, 10% more seedling emergence was observed in 10P soil compared to 50P soil, and emerged seedlings were very weak. In another experiment where Phi was applied as a foliar treatment, >95% control of Palmer amaranth and 65% control of johnsongrass were recorded at 256X rate, and the levels were generally comparable between 10P and 50P soils. In these experiments, non-transgenic (non-*ptxD*) cotton incurred <40% injury whereas the transgenic (*ptxD*) variety showed < 25% injury at the maximum and plants recovered rapidly. Preliminary results show that selective fertilization with Phi has the potential to provide effective suppression of Palmer amaranth and johnsongrass. However, additional investigations are required to optimize the dose and field utilization and understand the additive impact of crop competition.

First Report of Multiple Herbicide Resistance in Ragweed Parthenium (*Parthenium hysterophorus* L.) from Texas. Shilpa Singh*[1], Vijay Singh[2], Joshua A. McGinty[3], Muthukumar V. Bagavathiannan[1]; [1]Texas A&M University, College Station, TX, [2]Virginia Tech, Painter, VA, [3]Texas A&M AgriLife Extension Service, Corpus Christi, TX (214)

Ragweed parthenium (*Parthenium hysterophorus* L.) is an emerging weed problem in parts of the Texas Gulf Coast, and anecdotal evidence suggests potential occurrence of biotypes resistant to glyphosate, atrazine, and paraquat. Bioassays were conducted in the greenhouse at Texas A&M University, College Station to evaluate 45 parthenium biotypes collected from the Lower and Upper Gulf Coast regions of Texas. Seedlings (4-6 leaf) were treated with recommended field rates (1X) of glyphosate (868 g ae ha^{-1}), atrazine (1120 g ai ha^{-1}), and paraquat (560 g ai ha^{-1}). Initial screening was followed by a dose-response assay with eight rates (0.125, 0.25, 0.5, 1, 2, 4, 8, and 16X) for the highly resistant parthenium population for each herbicide and six rates (0.125, 0.25, 0.5, 1, 2, and 4X) for the susceptible population (SUS). The experiment was conducted twice in a completely randomized design with 3 replications and 15 plants per replication. Injury was recorded at 21 days after treatment (DAT) for glyphosate and atrazine and at 3 and 14 DAT for paraquat. At the 1X rate of glyphosate, 44% of the 45 populations were completely controlled; 20% had an average injury of 85%; and the remaining 36% had survivors with injury ranging from 35-75%. Nine (20%) populations were completely controlled with atrazine (1X); four populations had 75-85% injury and the remaining 32 populations had an average of 40% injury. For paraquat, 43 out of the 45 populations had an average injury of 35% (3 DAT) and 15% (14 DAT) injury. The dose-response assays have shown that the GR, atrazine- and paraquat-resistant populations were 40-, 5- and 36-fold more resistant, respectively, compared to the susceptible standard. Further, a relative increase of 4-17 copies was observed in the 5-enolpyruvylshikimate-3-

phosphate synthase (*EPSPS*) gene for 9 GR populations. Gene sequence analysis did not show any of the previously known resistance conferring mutations in both *EPSPS* (GR) and *psbA* (atrazine-resistant). Therefore, it is likely that nontarget-site mechanism is responsible for resistance to atrazine and paraquat in the resistant populations, which require further investigations.

Effect of Four Summer Cover Crop Species and Planting Timing on Weed Suppression, Soil Moisture Dynamics, and Yield in Corn. Spencer L. Samuelson*, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (215)

With corn and grain sorghum harvested in late July in the Southeast Texas region, the availability of long-growing season provides a niche for weeds to flourish. The potential for seedbank replenishment by such post-harvest summer annual weed recruits is a real concern for growers in the region. However, this extended growing season also provides a unique opportunity for establishing cover crops to suppress post-harvest summer annuals as well as winter annual weeds, in addition to providing soil conservation, nutrient cycling, and other ecosystem benefits. A major hesitation for growers to implement cover cropping in the region is the perceived impact on soil moisture from cover crop growth, depleting soil moisture reserves available for the subsequent cash crop. The objective of this study was to determine the effect of four summer cover crop species (sorghum sudangrass, sunn hemp, buckwheat, and cowpea) and three planting timing (mid-August, early-September, and late-September) on subsequent corn establishment, weed suppression through cover crop residues, impact on soil moisture, and corn yield. The study was established at two locations: The Texas A&M University Research Farm, College Station, TX, and the Stiles Foundation Farm, Thrall, TX during late-summer 2018 and concluded by summer 2019. Cover crop planting timing during late summer had little effect on corn stand establishment and grain yield when compared to no cover treatments. Sorghum sudangrass and sunn hemp provided substantial suppression of post-harvest summer annual recruits, and also provided suppression of winter annual weeds through residue cover after termination by winter kill. Results provide valuable insights into cover crop species selection and planting timing for achieving the most benefits for a given production goal.

Evaluation of Non-chemical Tactics for Managing Johnsongrass (*Sorghum halepense*). Spencer L. Samuelson*, Leonard Herndon, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (216)

Johnsongrass (*Sorghum halepense*) is a troublesome weed in agronomic crop fields, pastures, and non-crop areas throughout South Texas and beyond. This species is particularly a serious concern in organic systems, where tools available for effective management are very limited. Due to the mild winters in Southeast Texas, effective winter kill of johnsongrass rhizomes is not often achieved. As a result, rhizomatous johnsongrass begins to emerge as early as February in the region, and seedling johnsongrass beginning to emerge in March and throughout the season. The objective of this experiment was to determine how various non-chemical weed management tactics implemented in that fall after crop harvest impact the spring establishment of johnsongrass. The study is being conducted at the Texas A&M field research facility in Burleson County, TX. The treatments include variations of tillage, mowing, non-synthetic herbicides, and prolonged flooding. The experiment was arranged in a randomized complete block design with four replications.

Findings from this research hopefully will allow for the development of effective non-chemical options for managing johnsongrass.

Synthesizing Images for Semantic Segmentation of Weed Species in an Airborne RGB Imagery. Chengsong Hu*[1], Bishwa B. Sapkota[1], Steven B. Mirsky[2], Muthukumar V. Bagavathiannan[1]; [1]Texas A&M University, College Station, TX, [2]USDA-ARS, Beltsville, MD (217)

Airborne RGB imagery from unmanned aerial vehicles (UAV) has shown great potential for weed mapping in agricultural fields. The main challenge limiting its use for precision weed management is accurate detection and classification of weeds from crops. Recent developments in semantic segmentation, the process of classifying each pixel in an image using artificial neural networks (ANN), have achieved considerable success in several sectors. However, the use of ANN-powered semantic segmentation in agriculture, particularly for weed management applications has been impeded by a lack of large training dataset. We propose a method to fill the gap between the state-of-the-art ANN performance and the lack of annotated images in weed science domain, by synthesizing images using high-resolution plant and soil segments from ground-borne RGB imagery. The pipeline of our method involves 1) stochastically synthesizing realistic soil texture; 2) affixing weed and crop segments from ground-borne imagery to the soil texture, rapidly generating composite images and ground truth annotations; 3) rescaling composite images to match the resolution of airborne imagery; 4) training ANN with rescaled composite images and ground truth annotations; and 5) segmenting airborne imagery using trained ANN. The proposed method was tested with ground-borne (1.8 m above ground) and air-borne (10 m above ground) imageries taken at the same time in a cover crop field. Good segmentation results were achieved using only about 100 plant segments from one ground-borne image. The results indicate that synthetic data has great potential to reduce the need for a large annotated dataset for weed detection and mapping.

Virtual Agriculture: Modeling 3D Structure and Phenological Developments of Crops and Weeds. Chengsong Hu*, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (218)

Recent developments in precision weed management (PWM) are increasingly reliant on artificial intelligence (AI) technologies such as convolutional neural networks and high-performance computation, leading to more accurate and faster weed detection. However, these technologies are highly data-intensive and require a large number of well-prepared images. Unfortunately, the complexity of agricultural environments makes high quality data acquisition difficult. To help overcome the challenges of data deficiency that have long been hampering the adoption of AI in PWM, we focus on creating photorealistic images from virtual agricultural scenes by modeling 3D structure and phenological developments of crops and weeds. The workflow involves three major steps: 1) gathering plant leaf shape and color information; 2) modeling time-dependent 3D structures of plants; and 3) rendering in computer programs to generate photorealistic images. Shape and color information for individual leaves were collected using photometric stereo, a computer vision technique that estimates the shape of a surface by observing that surface under different lighting conditions. This information was then used to generate 3D leaf models. The orientation and position of stems and leaves of a plant were generated by L-system, a system that procedurally describes plant growth processes. Finally, plant models were augmented in the virtual scenes and rendered with different light settings. Countless photorealistic images and highly accurate ground-truth annotation can be generated with minimum amount of plant data. Powered with this technique, AI algorithm development for PWM will be largely accelerated and the requirement for large volumes of data in real-world applications can be minimized.

Dry Bean Responses to 2,4-D Ester Applied Preplant and Preemergence. ader Soltani*, Peter H. Sikkema; University of Guelph, Ridgetown, ON, Canada (219)

Six field studies were carried out in Ontario (during 2016 to 2018) to assess the tolerance of adzuki, kidney, small red and navy bean to 2,4-D ester at 528 or 1056 g ai ha^{-1} applied 14, 7 and 1 day before seeding (PP) and 3 days after seeding (PRE). 2,4-D applied PP or PRE caused as much as 4, 6, 7 and 8% injury in adzuki, kidney, small red and navy (white) bean, respectively. There was an increase in bean injury as the preplant interval decreased. At 1 WAE, 2,4-D applied at 1056 g ai ha^{-1} 14, 7 and 1 day PP and 3 days after seeding caused up to 6, 10, 18 and 5% visible bean injury, respectively. The level of injury decreased over time with minimal bean injury (0 to 3%) at 8 WAE. Bean stand counts was similar to the non-treated control with 2,4-D applied at various timings except at 1 day PP when 2,4-D at the 2X rate decreased bean stand 13%. There was up to 23 and 43% decrease in bean dry weight with 2,4-D applied PP at 528 and 1056 g ai ha^{-1} 7 and 1 day PP, respectively. Bean height (6 WAE) was not affected by 2,4-D applied at various timings except at 1 day PP when 2,4-D (1056 g ai ha^{-1}) decreased bean height 10%. Additionally, there was no effect of 2,4-D treatments on bean maturity or yield. Based on these results, the safest times to apply 2,4-D are 14 days before seeding or PRE. Injury was higher when 2,4-D was applied 7 and 1 day PP. Injury was lower in adzuki bean compared to kidney, small red or navy bean.

Getting Rid of Weeds Through Integrated Weed Management. Claudio G. Rubione*[1], Mark VanGessel[1], Lauren M. Lazaro[2], Michael L. Flessner[3], Kara Pittman[3], Muthukumar V. Bagavathiannan[4], Lovreet S. Shergill[5], Steven B. Mirsky[6], Victoria Ackroyd[7]; [1]University of Delaware, Georgetown, DE, [2]Louisiana State University AgCenter, Baton Rouge, LA, [3]Virginia Tech, Blacksburg, VA, [4]Texas A&M University, College Station, TX, [5]USDA-ARS & University of Delaware, Beltsville, MD, [6]USDA-ARS, Beltsville, MD, [7]USDA, Beltsville, MD (220)

Integrated weed management (IWM) combines various methods to reduce or eliminate the effect of weeds on crop production over time. These weed management methods form a “toolbox” in which “tools” can be integrated into a weed management plan catered to the particular farm and problem. The toolbox includes preventative, biological, chemical, cultural, and mechanical strategies. IWM also considers the weed species present and tailors strategies for these species. In conventional crops, integrated weed management is not a replacement for herbicides. For many decades, herbicides have been the primary means of weed management due to their simplicity, effectiveness, and affordability. However, relying too much on a few herbicides has led to an increase of weed species that are not effectively controlled with the herbicide program or selecting for herbicide-resistant biotypes. IWM approaches go beyond relying on herbicide rotation and mixtures. IWM programs use all available methods that will best solve the problem. To expand the use of IWM, GROW was developed as part of an USDA-ARS Area-Wide Project. GROW

(Get Rid Of Weeds) is a place to find helpful, research-based resources for integrated weed management for herbicide-resistant weeds. GROW uses the website www.growiwm.org as a main source of information, as well as social media accounts (Tweeter, Instagram, YouTube and Facebook). The website provides a resource for general interest content on IWM, current and ongoing research projects, and more in-depth information on specific management strategies. When navigating GROW's website users can either browse for general information such as “What is IWM?” or “A-B-C's of IWM Principles” or go into more specific areas such as “IWM Toolbox” or “Resistant Weeds”. The website is currently undergoing a new design to improve the user experience. GROW is an opportunity for anyone working on IWM to have a platform to expand their reach and always looking for new partners.

Harvest Weed Seed Control in Wheat Production Systems of the PNW. Judit Barroso*[1], Carolina San Martin Hernandez[2], Jennifer A. Gourlie[1], Stewart B. Wuest[3], Mark Thorne[4], Kyle Roerig[5], Andrew G. Hulting[5]; [1]Oregon State University, Adams, OR, [2]Oregon State University, Pendleton, OR, [3]USDA-ARS, Adams, OR, [4]Washington State University, Pullman, WA, [5]Oregon State University, Corvallis, OR (221)

Harvest weed seed control (HWSC) might perform an important role in controlling problematic weeds, by decreasing the weed seed bank. However, HWSC practices will not be effective if plants have previously shed all or a great part of their seeds before harvest, or if the combine is unable to collect the seed. The objectives of this study were: 1) evaluate the efficacy of chaff collection and chaff plus straw collection to reduce weed infestations and dispersion, 2) evaluate seed production, seed height, and seed retention of important weed species at harvest, and 3) determine the effects of chaff or chaff and straw removal on soil organic matter and moisture content. After two harvest season, in three studied farms, the collection of chaff did not produce significant differences in weed infestation compared to the control treatment (no residue removal). The collection of chaff and straw (bale direct system) provided marginally significant *Sisymbrium altissimum* reduction (10.6% on average) on one of the farms and a reduction tendency in the other farm with this problematic species. *Bromus tectorum*, *L. perenne* ssp. *multiflorum*, *Vulpia myuros*, and *Chorispora tenella* had an average seed retention at harvest of less than 50%. In addition, the low seed retention height in *V. myuros* and *C. tenella* makes these species poor candidates for HWSC. *Sisymbrium altissimum* and *Secale cereale* had average seed retention at harvest greater than 50% and seed retention height above 30 cm. The efficacy of HWSC practices in the PNW winter wheat cropping systems will be species dependent. While no differences have been found in soil carbon due to chaff or chaff and straw removal compared to the control, the collection of chaff plus straw caused a statistically significant reduction in gravimetric soil moisture (2 mm of precipitation per month) in the top 30 cm of soil. In arid and semi-arid areas, where the soil water accumulation is important, the removal of straw may not be a profitable practice.

Evaluation of Herbicides for Potential Use in an Integrated Release Method of *Trichogramma ostriniae*. Jeffrey D. Cluever[1], Robert Wright[2], Nevin Lawrence[1], Jeff Bradshaw*[1]; [1]University of Nebraska-Lincoln, Scottsbluff, NE, [2]University of Nebraska-Lincoln, Lincoln, NE (222)

Trichogramma ostriniae is a hymenopterous egg parasitoid which has been used successfully as a biological control agent of lepidopterous pests, including the sugarcane gray borer (*Argyroploce schistaceana*), the European corn borer (*Ostrinia nubilalis*), and the Asian corn borer (*O. furnacalis*). Typical biological control field releases use at most a few point source releases. However, significant advantages may be gained from the use of multiple release points, such as broadcast releases. Broadcast releases may be facilitated through the additional use of carriers, such as water, sawdust, stickers, and bran. However, the broadcast release of *Trichogramma* via herbicide applications has not been attempted, though it may prove to be an economically feasible, since dry bean growers usually apply an herbicide shortly prior to the time of western bean cutworm (*Striacosta albicosta*) flight. Applying *T. ostriniae* in an herbicide tank mix may prove to be an economical method of broadcast release. Herbicides and adjuvants common to dry bean production were assessed for toxicity to *T. ostriniae* pupae. Parasitized *Ephestia kuehniella* eggs were immersed in these solutions for various time intervals. After removal, the parasitized eggs were held at room temperature and assessed for emergence. Results like these will enable growers to more effectively use biological control agents like *Trichogramma*.

Control Alternatives in *Carduus acanthoides* Resistant to 2,4-D and Glyphosate. Candelario Palma-Bautista*[1], Pablo Belluccini[2], Valentin Gentiletti[3], Jose G. Vazquez García[1], Antonia M. Rojano-Delgado[1], Rafael De Prado[1]; [1]University of Cordoba, Cordoba, Spain, [2]INTA Marcos Juarez, Cordoba, Argentina, [3]ETS Ingenieros Agronomos, Camilo Aldao, Argentina (223)

Carduus acanthoides L. is an invasive species that belongs to the Asteraceae family native to Europe and is distributed in other parts of the world, such as North and South America. In Córdoba, Argentina, control failures of this species have been reported in soybean and RR corn crops where weed control with glyphosate and 2,4-D is carried out. A suspicious population (R) with failures in the control of these herbicides was compared with a sensitive population (S) with no history of application of herbicides collected 20 km from the suspect site. Dose-response tests confirm multiple resistance to glyphosate and 2,4-D because population R showed an LD_{50} of 1854 and 1577 g ae ha^{-1} respectively, while for population S it was 196 and 112 g ae ha^{-1}, for each herbicide. Low accumulation of shikimic acid (glyphosate) and ethylene (2,4-D) at different herbicide concentrations in the R population compared to the S population supports the results observed in the dose-response assay. The use of adjuvants improves efficacy by 12-24% and 18-28% for both glyphosate and 2,4-D herbicides. Ten alternative herbicides with seven different mechanisms of action (MOA) were evaluated and the best were: dicamba, bromoxynil, atrazine, tembotrione, flazasulfuron, glufosinate and paraquat with 100% control. These results show the first evidence of multiple resistance in *C. acanthoides* in the world. Chemical control alternatives and the use of adjuvants could be future control tools for farmers.

Efficacy of Indazaflam on Downy Brome Control in Northern Nevada. Charlie D. Clements*; USDA-ARS, Reno, NV (224)

The accidental introduction and subsequent invasion of downy brome (Bromus tectorum) throughout millions of hectares of Intermountain West rangelands has resulted in astronomical changes to many plant communities. Downy brome is native to the cold deserts of central Asia where humans are first thought to have domesticated animals. These native habitats are very similar to the big sagebrush (Artemisia tridentata)/bunchgrass and salt desert ranges of the Intermountain Area of North America. Resource managers need tools to conduct aggressive and effective weed control practices on downy brome-infested rangelands to improve restoration/rehabilitation efforts. The use of pre-emergent herbicides can provide the opportunity to be very effective in decreasing downy brome densities and seed banks which are limiting to the establishment of perennial species through competition for limited resources. Indazaflam, Esplanade, is a pre-emergent herbicide recently available for research on Nevada rangelands. In 2018 we started a research project to measure the efficacy of Indazaflam on downy brome control in northern Nevada compared to other pre-emergent herbicides that have experienced sufficient downy brome control such as Imazapic and Sulfometuron methyl. Due to the environments of the cold desert of Nevada rangelands, we applly these pre-emergent herbicides in the fall of the year, fallow the site for 1-year and then seed with desirable perennial species. Indazaflam plots reduced downy brome initial densities by 94.8%, while Sulfometuron methyl experienced 99.9% followed by 97.8% for Imazapic. Indazaflam treated plots, however experienced significantly lower seed bank densities 1-year following application. When attempting downy brome control efforts it is important to understand that control must nearly reach 100% due to the prolific ability of downy brome to produce seed and build persistent seed banks. As few as 43 downy brome seedlings/m² can outcompete perennial grasses at the seedling stage. The reported residual ability of Indazaflam for up to 4-years and significant reductions in downy brome seed banks may add longer-term control of downy brome that could benefit residual and seeded perennial species.

Total Weed and Nutsedge Populations in Fall Vs. Spring Planted Crops Following Different Cultivation Types and Frequency During the Fallow Period. Peter J. Dittmar*, Danielle D. Treadwell; University of Florida, Gainesville, FL (225)

Two cultivation events or glyphosate applications during a 14 week fallow period can reduce the nutsedge population in fall planted vegetable crops. The study objective was to evaluate weed control in fall or spring vegetable crops following different types and frequencies of cultivation during seven weeks of fallow management. The treatments included rotavator, s-tine, or tine cultivators at 3x or 6x during the fallow, cover crop, glyphosate, and a nontreated. The cover crop was pearl millet and iron clay pea in the fall trial and winter wheat and Austrian pea in the spring trial. Glyphosate at 0.29 kg ae ha^{-1} was applied with a backpack sprayer calibrated to deliver 30.6 L ha^{-1}. The entire field was cultivated [0 wk after initial treatment (WAI)] for even nutsedge emergence prior to beginning the treatments. Weeds were counted by species ever week prior to cultivation, weed biomass was collected at the end of the fallow and cash crop, and cash crop at maturity. The fall trial included bok choy and the spring trial included green bean. At the end of the fall fallow period (7 WAI) glyphsoate, rotavator, and s-tine had the lowest nutsedge population. Tine cultivation and cover crop had similar nutsedge population to the nontreated. At the end of the spring fallow, only rotavator and s-tine had similar nutsedge populations. At bok choy harvest (14 WAI), nutsedge populations in glyphosate, rotavator, and s-tine were similar to cover crop and nontreated. At the end of the green bean, glyphosate and all the cultivators type had similar nutsedge counts. The total weed counts at the end of the fallow period were similar to nutsedge populations. At the end of the crops, grass and broadleaf weed populations were so high that differences were not measured between treatments. In the fall fallow, the cover crop contributed more organic material to the system than the weeds in the other treatments. After the spring fallow period, the weeds in the nontreated and tine treatments contributed a greater amount of organic material than the cover crop. No differences were measured between the crop biomass. Cultivation during the summer months had a greater effect on lowering nutsedge populations during the cash crop compared to cultivation during the winter months prior to a spring planted crop.

Broadleaf Weed Population and Diversity Following Different Cultivation Types and Frequency Before Fall or Spring Vegetable Crops. Peter J. Dittmar*, Danielle D. Treadwell; University of Florida, Gainesville, FL (226)

The fallow period prior to planting vegetable crops allows for nonselective herbicides, intense cultivation, and cover crops, which are not available during the cash crop. The study objective was to evaluate broadleaf weed control in production systems with different types and frequencies of cultivation prior to planting fall or spring vegetable crops. The cultivation treatments included were rotavator, s-tine, and tine cultivators 3x or 6x during the fallow period. The additional treatments were cover crops, glyphosate, and a nontreated. The vegetable crop was planted after an eight week fallow period in the fall trial bok choy was planted and the spring trial was green bean. In the fall trial fall period, rotavator, s-tine, and glyphosate had the fewest number of broadleaf species. The three most common weeds in these treatments during the fall trial fallow were *Commelina communis*, *Ipomoea coccinea*, *Physalis angulata*, *Desmodium tortuosum*, and *Sida rhombifolia*. In the bok choy, the most common species were *Raphninus raphanistrum*, *Richardia scabra*, and *Oenothera laciniata*. In the spring trial fallow period, all of the cultivator treatments and glyphosate had a similar number of broadleaf species. The most common species during the spring fallow period and green bean were *Raphninus raphanistrum* and *Richardia scabra*. *Physalis angulata* was in the spring fallow period only. During the fall and spring trial, glyphosate, rotavator, and s-tine had the lowest broadleaf population. The broadleaf population in the vegetable crop was not different among all the treatments. The temperatures during the fall fallow were higher than the temperatures during the bok choy. The temperatures during the spring trial fallow period were similar to the temperatures during the first three weeks of the green bean crop. These temperature differences caused no broadleaf weed control in the fall trial. However, in the spring trial similar broadleaf weed species during the fallow and green bean allowed for lower broadleaf weed populations.

Using Unmanned Aerial Systems for Early Prediction of Competitive Interactions Between Italian Ryegrass (*Lolium perenne* Ssp. *multiflorum*) and Wheat. Bishwa B. Sapkota*[1], Vijay Singh[2], Clark Neely[3], Muthukumar V. Bagavathiannan[1]; [1]Texas A&M university, College Station, TX, [2]Virginia Tech, Painter, VA, [3]Washington State University, Pullman, WA (227)

Italian ryegrass (*Lolium perenne* ssp. *multiflorum*) is a highly competitive weed in winter wheat (*Triticum aestivum*), severely affecting its growth and yield. Estimation of ryegrass infestation in wheat fields and early prediction of its competitive impact on wheat grain yield can assist farmers with management decision making. To investigate this, two independent field experiments were conducted at College Station, Texas, during the 2019 field season. In this study, digital images obtained using an unmanned aerial system (UAS) (DJI Phantom 4) at an early wheat growth stage was utilized for predicting end-of-season ryegrass biomass and seed production as well as wheat biomass and yield reduction (%). Artificial Neural Networks were used to detect and map ryegrass infestation in wheat field. The coverage (%) of ryegrass estimated using image analysis was regressed against end-of-season above ground biomass and seed yield of ryegrass and wheat to develop predictive models. The models developed in this research showed high to very high prediction accuracies, with r^2 values of 0.87, 0.74, 0.72, and 0.69 for ryegrass biomass, ryegrass seed yield, wheat biomass, and wheat yield reduction (%), respectively. Results showed that UAS imagery collected using early growing season can be utilized to reliably predict competitive outcomes between Italian ryegrass and wheat by the end of the season.

Advanced Machine Learning Approaches for Evaluation of Herbicide Drift Injury in Cotton. Bishwa B. Sapkota*, Muthukumar V. Bagavathiannan; Texas A&M university, College Station, TX (228)

Off-target movement of herbicides onto sensitive crop cultivars is a serious concern in agricultural landscapes. An ability to detect and assess herbicide injury on crops using drone images and advanced machine learning algorithms can allow for rapid and informed decision making by growers regarding contingency plans. To accomplish this, both multispectral and RGB imagery-based approaches were implemented in this study. The spectral response of young cotton plants to tembotrione (Laudis®), 2,4-D, and chlorimuron (Classic®) were recorded with DJI Matrice 600 drone mounted with a multispectral camera (Micasense RedEdge) and DJI Phantom 4 drone mounted with a standard RGB camera, at 7, 14, and 21 days after herbicide application (DAA). Two different spectral indices namely Normalized Difference Vegetation Index (NDVI) and Chlorophyll Vegetation Index (CVI) were developed and compared on the spectral signatures. Further, a graphical user interface (GUI) was developed using a deep neural network model trained with several true color imageries for crop injury acquired with the DJI Phantom 4 drone. The GUI was designed to recognize the herbicide based on the unique injury patterns detected using the true color imagery. Preliminary results showed that NDVI was significantly different for all the herbicides at 14 and 21 DAA, while CVI was significantly different at 7 and 21 DAA. NDVI values were the greatest for the plants with no drift effect, followed by the plants injured by chlorimuron, tembotrione, and 2,4-D for all observation timings. CVI was the greatest for 2,4-D, followed by chlorimuron, non-drifted check, and tembotrione. The neural network model showed high performance in identifying the herbicide for all observation timings tested, with 85% accuracy for 7 DAA, 90% for 14 DAA, and 80% for 21 DAA. The spectral responses recorded, and the GUI developed in this study will be of great value to farmers for assessing herbicide drift in production fields.

Weed Classification Using Unmanned Aerial Systems-based Imagery. Vijay Singh*[1], Chi Zhaohui[2], Da Huo[2], Michael Bishop[2], Anthony Filippi[2], Muthukumar V. Bagavathiannan[2]; [1]Virginia Tech, Painter, VA, [2]Texas A&M University, College Station, TX (229)

Recent advances in imaging sensors and unmanned aerial systems have improved the efficiency of precision weed management. Likewise, exploring alternate image analysis techniques can be invaluable in diagnosing and assessing weed infestations and facilitating weed management. Field and greenhouse studies were conducted during 2017 at College Station, TX to identify various weed species and determine their density in soybean, sorghum, corn and cotton fields. Images (Rd-

Green-Blue; RGB) were collected using DJI Phantom-4 at 35 days after planting. RGB image data was subjected to frequency analysis and coefficients were calculated using Continuous Wavelet Transformation (CWT). The differences in preemergence and postemergence herbicide treatments or different densities of weeds could be easily detected with structural frequency variations where the variation range of wavelet coefficient mean is lower in properly managed plots. It has been observed that geometry and architecture of leaf arrangement affects its structural frequency estimations which is helpful in differentiating different crops & weeds. The variation range of wavelet coefficient mean was in order of sorghum>Soybean>Cotton>Corn. The lower coefficient mean indicates higher similarity of leaf arrangement and vice versa. These features have the potential to be used for diagnostic weed species classification.

Efficacy of Unmanned Aerial System-based Herbicide Applications. Vijay Singh*[1], Daniel Martin[2], Mohamed Latheef[2], Bishwa B. Sapkota[3], Muthukumar V. Bagavathiannan[3]; [1]Virginia Tech, Painter, VA, [2]United States Department of Agriculture, College Station, TX, [3]Texas A&M university, College Station, TX (230)

The use of unmanned aerial systems (UAS) is not only limited to mapping or classification of weeds. These systems have the potential for managing weeds with herbicide spray applications. The UAS with spray systems are more economical and easy to use compared with manned aircraft systems due to their ability to hover and fly at low speed and altitude. Studies were conducted in summer 2018 and 2019 at College Station, TX to evaluate the efficacy of UAS spray technologies for postemergence herbicide application in comparison to conventional backpack sprayer. Two separate studies were conducted using 1) florescent dyes, 2) herbicides; glyphosate and glufosinate. Grass and broadleaf weed seeds were broadcasted one week after soybean planting and weed density was recorded before spray application. A spray mixture was applied on Palmer amaranth (*Amaranthus palmeri*) and ivyleaf morningglory (*Ipomoea hederacea*) with a remotely piloted UAS aircraft at 18.7 (UAS-2) and 37.4 L ha^{-1} (UAS-4) and a CO_2 pressurized backpack sprayer at 140 L ha^{-1} (BP-15). Two types of artificial samplers, water-sensitive papers (WSP) and Mylar cards were deployed to determine droplet spectra and spray deposits, respectively. Droplet images on WSP samplers and fluorescent droplets on weed leaves were analyzed using a commercial imaging and Java-based ImageJ software, respectively. Mylar deposition was determined by fluorometry. These experiments were conducted as a completely randomized block design with four replications and were repeated two weeks later. Spray application treatments showed significant differences in droplet density at the top and bottom surfaces of the leaves. UAS-based spray applications resulted in a higher droplet percentage (?25% of total applied) at abaxial surface compared with backpack spray application (4% of total applied) which may help in increasing the efficacy of contact herbicides. Both UAS based herbicide (glufosinate) treatments provided >90% weed control which was greater than weed control (75%) achieved with backpack spray applications when glufosinate applied late-POST.

Nozzle Type Effect on Coverage, Canopy Penetration, and Weed Control Using Enlist One and Liberty in Enlist E3 Soybeans. Ashley N. McCormick*[1], Troy W. Dillon[2], Brad M. Davis[2], Thomas R. Butts[2], Collie M. Leah[2]; [1]University of Arkansas System Division of Agriculture, Newport, AR, [2]University of Arkansas System Division of Agriculture, Lonoke, AR (231)

Chemical applicators have many variables to account for when applying herbicides. Some of these variables include spray coverage, canopy penetration, and herbicide selection. It is important for applicators to know and understand how nozzle selection impacts these variables, especially for the particular herbicide being used. The objective of this research was to evaluate how droplet size and nozzle type impact spray coverage and canopy penetration. Field experiments were conducted during the summer of 2019 at the University of Arkansas System Division of Agriculture Rohwer Research Station near Rohwer, AR and the Newport Extension Center near Newport, AR in soybean planted in 97-cm row widths and drilled in 19-cm row widths, respectively. Applications were made using 140 L ha^{-1} and 94 L ha^{-1} at the Newport and Rohwer sites, respectively, with a Bowman MudMaster (Bowman Manufacturing Co., Inc., Newport, AR 72112). Treatments consisted of four nozzle types [AIXR, AITTJ60, TTI, and TTI60 (TeeJet Technologies, Wheaton, IL 60187)], three chemical treatments [2,4-D choline (Enlist One), glufosinate (Liberty), and 2,4-D choline (Enlist One) + glufosinate (Liberty) tank-mixture], and a nontreated control. This provided a total of 13 treatments. The nozzle types were selected to allow comparisons between single-fan (AIXR and TTI) and dual-fan (AITTJ60 and TTI60) nozzles. The emitted droplet size was similar between the AIXR and AITTJ60 (Very Coarse) nozzles and between the TTI and TTI60 (Ultra Coarse) nozzles. Data collected consisted of three water sensitive paper spray cards located at two locations within the canopy for a total of six spray cards per plot. At the top of the canopy, cards were oriented as follows: one horizontal card (top), a vertical card facing towards the direction of the sprayer (front), and a vertical card facing away from the direction of the sprayer (back). These same three card directions were placed within the soybean canopy, 15-cm from the soil surface. Water sensitive cards were analyzed for spray coverage using DepositScan (USDA-ARS Application Technology Research Unit, Wooster, OH 44691). Data were then subjected to ANOVA using SAS v9.4 (SAS Institute, Cary, NC 27513) and means were separated using Fisher's Protected Least Significant Difference Test at a=0.05. Due to the greater spray volume used, greater coverage on the top canopy cards was achieved at the Newport site compared to the Rohwer site. However, greater coverage on the within canopy cards was achieved at Rohwer compared to Newport most likely due to wide rows (97-cm) compared to drilled rows (19-cm) allowing easier droplet penetration into the canopy even with a reduced total spray volume. At both locations, greater coverage was achieved depending on the herbicide treatment in the order of glufosinate > 2,4-D choline + glufosinate > 2,4-D choline due to changes in droplet size. Nozzle type did not influence coverage to a large extent. This research indicates the tested dual fan nozzles (AITTJ60 and TTI60) did not provide greater coverage than their single fan counterparts (AIXR and TTI). Instead, factors such as droplet size and agronomic characteristics (row width) played a greater role in spray coverage.

Reimagining the Use of Electricity to Kill Weeds. Erik A. Lehnhoff*, Donovan Bailey, Paul Neher; New Mexico State University, Las Cruces, NM (232)

Weed management in urban and suburban areas is challenged by a lack of safe and effective control measures. Some cities have banned the use of some or all herbicides on public property, and many homeowners choose to not use herbicides. Hand pulling weeds is difficult and often ineffective because perennial weeds may re-grow. For woody weeds, cutting is usually ineffective because it may promote regrowth from many stems and digging out the plants may damage structures or adjacent landscaping. We have developed a method using electricity to safely and effectively manage weeds. Our method uses a direct current with a constant amperage, allowing voltage to vary as resistance changes. For controlling herbaceous vegetation we connect the current source to a wire mesh which is laid over the plants. This method can also be used for pre-emergent control. Buried under landscaping gravel, this provides permanent weed control at a low cost. To kill larger woody plants, current is delivered to the tree by attaching the current source to a screw or nail placed in the tree near the root crown. For both herbaceous and woody plants, the amperage is very low, and safety features are built in to shut off the system if resistance drops too low, for example if the ground is wet. We have successfully used the technology to selectively kill woody species such as Siberian elm (*Ulmus pumila*), mulberry (*Morus* spp.) and mesquite (*Prosopis glandulosa*), and numerous herbaceous species including Bermudagrass, (*Cynodon dactylon*), purslane (*Portulaca oleracea*) and Palmer amaranth (*Amaranthus palmeri*). Our methods provides a new tool for weed control in areas such as landscaping, right of ways, and city parks. Additional research is ongoing to expand the use of these systems to agricultural settings.

Competition Between Canada Thistle and Crops in Organic Cropping Systems of the Northern Great Plains. Daniel Chichinsky[1], Tim Seipel*[1], Perry Miller[1], Fabian D. Menalled[1], Patrick Carr[2], Greta G. Gramig[3]; [1]Montana State University, Bozeman, MT, [2]Montana State University - Central Ag Research Center, Moccasin, MT, [3]North Dakota State University, Fargo, ND (233)

Integrated biological, cultural, and mechanical management techniques are needed to suppress perennial weeds in organic cropping systems in the Northern Great Plains. As part of integrated weed management, crop-weed competition has the potential to suppress weeds and limit yield loss. The aim of this research was to determine which annual crop is most competitive with the rhizomatous perennial weed Canada thistle (Cirsium arvense). At two Montana State University research centers and multiple collaborating farms in Montana and North Dakota, we assessed how Canada thistle biomass and stem density responded to spring wheat, lentil, a cover crop mixture, and barley. At each site, the crop treatments were replicated four times. Within each plot, crop and Canada thistle density was counted. Crop biomass and Canada thistle biomass were harvested in three 1m2 frames within each plot. Generalized linear mixed-effects models were used to assess the effects of crop density (or biomass) on Canada thistle density and biomass using ANOVA and post-hoc comparisons. Crop and Canada thistle biomass varied among the eight experimental sites but were consistently negatively correlated. The suppression of Canada thistle was similar among the different crop species but both crop and weed biomass varied in response to local climate conditions. Crops common to the Northern Great Plains the selected cover crop mixtures were not competitive with Canada thistle especially at high density and are unlikely to provide effective suppression of Canada thistle without integrating multiple weed management methods.

Integration of Cultural Practices and Herbicides for Weed Control in Grain Sorghum and Soybean. Vipan Kumar*[1], Rui Liu[1], Natalie Aquilina[1], Taylor Lambert[1], Ramsamy Perumal[1], Troy Ostmeyer[1], Andrew Tucker[2]; [1]Kansas State University, Hays, KS, [2]Fort Hays State University, Hays, KS (234)

Glyphosate-resistant (GR) kochia (*Kochia scoparia*) and Palmer amaranth (*Amaranthus palmeri*) are increasing management challenge for growers in western and central Kansas. Development of integrated weed management (IWM) strategies are needed for controlling GR kochia and Palmer amaranth in this region. Two separate field experiments were conducted at Kansas State University Agricultural Research Center near Hays, KS in 2018 and 2019 to understand the role of cultural practices in combination with herbicides for weed control in grain sorghum (experiment 1) and soybean (experiment 2). Experiment 1 was comprised of two cold-tolerant sorghum hybrids: Pioneer 87P06 and ATx645/ARCH12012R; two row spacing: 38 and 76 cm; and three herbicide programs: (A) acetochlor at 1,890 g ha^{-1} plus atrazine at 938 g ha^{-1} PRE, (B) acetochlor at 1,890 g ha^{-1} plus atrazine at 938 g ha^{-1} PRE followed by (*fb*) bromoxynil at 230 g ha^{-1} plus pyrasulfotole at 40 g ha^{-1} POST, and (C) a nontreated weedy check. Experiment 2 was comprised of three soybean seeding rates (250,000, 375,000 and 500,000 seeds ha^{-1}); two row spacing (38 and 76 cm); and two herbicide programs: (A) PRE applied sulfentrazone + metribuzin (127 + 191 g ha^{-1}) followed by (*fb*) a POST treatment of glyphosate + dicamba (1260 + 560 g ha^{-1}), and (B) a nontreated weedy check. Both experiments were conducted in a randomized complete block design with factorial arrangement of treatments and 3 to 4 replications. Study site in experiment 1 was uniformly infested with a GR Palmer amaranth population prior to sorghum planting. Data on density and percent visual control of GR Palmer amaranth were recorded at biweekly interval throughout the growing season. Shoot dry weights of GR Palmer amaranth were determined prior to crop harvest and sorghum grain yields were recorded at crop harvest. In experiment 2, a glyphosate plus dicamba-resistant soybean variety 'AG34X7' was utilized and study site had natural infestation of glyphosate-resistant (GR) kochia and Palmer amaranth. Data on percent visual control, and weed density were recorded at bi-weekly intervals throughout the growing season. Total weed biomass was determined prior to crop harvest and soybean grain yield was recorded at harvest. Results from experiment 1 indicated that both PRE alone and PRE *fb* POST programs provided an excellent, season-long control (>97%) of GR Palmer amaranth. In non-treated weedy plots, GR Palmer amaranth density was not affected by sorghum hybrid or 38-cm row spacing; however, its shoot dry weight was reduced by 37% with 38 compared to 76 cm rows. Sorghum grain yield of Pioneer 87P06 was increased by 27% in 38-cm compared to 76-cm rows; whereas, row spacing had no effect on grain yield of ATx645/ARCH12012R hybrid. Results from experiment 2 indicated that PRE applied sulfentrazone + metribuzin *fb* a POST treatment of glyphosate plus dicamba had an excellent, season-long control of GR Palmer amaranth and kochia. In the absence of any herbicide treatment, row spacing of 38-cm and soybean seeding rates (=375,000 seeds ha^{-1}) caused a reduction in total weed biomass. Altogether, these results from both experiments suggest that the cultural practices such as narrow row spacing (38 cm) in combination with effective herbicide program can potentially be utilized for season-long control of GR weeds in cold-tolerant sorghum and soybean.

Common Waterhemp (*Amaranthus tubercualtus*): Directed Energy Manangement of Weed Seed Bank in Corn. Cadance A. Lowell*[1], Marcus Nagle[1], Deng Cao[1], Jon Jackson[2]; [1]Central state university, Wilberforce, OH, [2]Global Neighbor, Inc., Centerville, OH (235)

Waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer) is a major herbicide-tolerant weed that significantly reduces yield in infested low to no-till fields across the Midwest, USA. Farmers use a battery of methods to keep waterhemp from emerging including pre-emergent herbicides, burn down and weed seedbank management. Current, non-chemical controls include cover crops, crimping, seeding rates, decreased row width, and flaming. Weed seed control at harvest includes chaff mills, chaff carts, bailing chaff and chaff burning. The purpose of this research is to evaluate the potential of using directed energy for weed seed control at harvest. A prototype device is being developed in a public-private partnership, as an integrated pest management strategy for broad leaf weeds. Chaff was collected during harvest from a waterhemp infested field in Lac qui Parle County, MN. Chaff was treated with 4 W/cm^2 of directed energy from a metal halide light source (340-2000 nm) for 15 or 30 sec using either a quartz (transmitting UVA/UVB) or borosilicate glass (blocking UVA/UVB) plate. After treatment, seeds were separated from the chaff and germinated at 90 degrees F in the dark with 100 seeds per dish, 3 dishes per treatment and control for a total of 1500 seeds. Control germination rates averaged 35%. There was no difference in germination rates ($p<0.05$) among treatments up to 15 days. Total number of seeds germinated ranged from 26% (glass, 15 sec) down to 4% (glass, 30 sec). Seeds from each treatment and control were planted in seed mix in pots with 50 seeds per pot, 4 pots per treatment. No seeds germinated from the glass treatment at 30 sec, while other treatments germinated similarly to the petri dish experiments. Directed energy from high intensity discharge lamps with a broad light spectrum does work to kill waterhemp seeds in chaff and prevents viable seeds from entering the seed bank. Experiments are underway to test this directed energy treatment on other broad leaf weed seeds collected after harvest from agricultural fields in Greene County, Ohio including marestail, evening primrose, burdock, and poison hemlock.

Impact of Cotton Desiccants on Seed Viability of Palmer Amaranth (*Amaranthus palmeri*).
Debalin Sarangi*[1], Kaisa M. Werner[2], Bojana Pilipovic[2], Peter A. Dotray[3], Muthukumar V. Bagavathiannan[2]; [1]University of Wyoming, Powell, WY, [2]Texas A&M University, College Station, TX, [3]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX (236)

Palmer amaranth is a highly competitive weed species with prolonged seedling emergence periodicity. Individuals that evade weed control interventions occur as escapes during late-season and contribute significantly to the weed seedbank. Application of harvest aids (desiccants) at cotton maturity is a common practice to facilitate crop harvest, but the impact of such desiccants on seed viability of Palmer amaranth is unknown. Experiments were conducted in 2018 at College Station, TX to evaluate the impact of cotton desiccants on seed viability of Palmer amaranth at different seed developmental stages (green, white, brown, and black). At 28 days after treatment at respective seed developmental stage, the seedheads were harvested, the number of fully developed and aborted (shriveled seed coat) seeds were counted, and the viability of fully developed seeds was tested. Results showed that viable seed production by Palmer amaranth was affected by desiccant treatment and seed development stage. Application of paraquat, glufosinate, MSMA, dicamba, 2,4-D, or pyraflufen-ethyl at black seed stage caused = 35% reduction in viable seed production compared to nontreated control. The aforementioned desiccants except pyraflufen-ethyl applied at early seed development stages (green and white stages) caused 76 to 98% reduction in Palmer amaranth seed viability. Findings indicate that late-season application of cotton desiccants can significantly reduce viable seed production in Palmer amaranth, depending on the choice of desiccant and the seed developmental stage at which applications are made.

THREE-MINUTE THESIS RESEARCH COMMUNICATION COMPETITION (3MT™)

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Halauxifen-methyl: A Tool for Managing Glyphosate-resistant Weeds. Jessica E. Quinn*[1], Nader Soltani[1], Jamshid Ashigh[2], David C. Hooker[1], Darren E. Robinson[1], Peter H. Sikkema[1]; [1]University of Guelph, Ridgetown, ON, Canada, [2]Corteva Agriscience, London, ON, Canada (237)

Canada fleabane is a competitive summer or winter annual weed that produces up to 230 000 small seeds per plant that are capable of travelling more than 500 km via wind. Giant ragweed is a tall, highly competitive summer annual weed. Glyphosate-resistant (GR) Canada fleabane and GR giant ragweed pose significant challenges for wheat producers in the United States and Ontario, Canada. Halauxifen-methyl is a new, selective, broadleaf, postemergence (POST) herbicide registered for use in cereal crops; there is limited information on its efficacy on GR Canada fleabane and GR giant ragweed. The purpose of this research was to determine the efficacy of halauxifen-methyl applied POST, alone and in a tank-mix, for the control of GR Canada fleabane and GR giant ragweed in wheat across southwestern Ontario. For each weed species, an efficacy study consisting of 6 field experiments was conducted over a two-year period (2018, 2019). At 8 weeks after application (WAA), halauxifen-methyl, fluroxypyr/halauxifen, fluroxypyr/halauxifen + MCPA EHE, fluroxypyr + MCPA ester, 2,4-D ester, clopyralid, and pyrasulfotole/bromoxynil + AMS controlled GR Canada fleabane >95%. Fluroxypyr and MCPA provided only 86 and 37% control GR Canada fleabane, respectively. At 8 WAA, fluroxypyr, fluroxypyr/halauxifen, fluroxypyr/halauxifen + MCPA EHE, fluroxypyr + MCPA ester, fluroxypyr/halauxifen + MCPA EHE + pyroxsulam, 2,4-D ester, clopyralid, and thifensulfuron/tribenuron + fluroxypyr + MCPA ester controlled GR giant ragweed 87, 88, 90, 94, 96, 96, 98 and 93%, respectively. Halauxifen-methyl and pyroxsulam provided only 45 and 28% control of GR giant ragweed, respectively. This study shows that halauxifen-methyl alone, applied POST in the spring, controls GR Canada fleabane, but not GR giant ragweed in winter wheat.

Diurnal Response to Dicamba and Glyphosate Applications on Broad-leaf Weed Species in Cotton. Jacob R. Kalina*[1], Timothy L. Grey[1], Christopher B. Corkern[2], Donn G. Shilling[3], Nicholas T. Basinger[3]; [1]University of Georgia, Tifton, GA, [2]Bayer Crop Sciences, Tifton, GA, [3]University of Georgia, Athens, GA (238)

Diurnal Response to Dicamba and Glyphosate Applications on Broad-leaf Weed Species in CottonJ.R. Kalina[1], T.L. Grey[1], C.B. Corkern[2], N.T. Basinger[1], D.G. Shilling[1] [1]The University of Georgia (UGA) Dept. of Crop and Soil Sciences [2]Bayer Crop ScienceRenewed interest in the study of Auxin herbicides (WSSA group 4) is increasing due to the release of genetically engineered crop varieties that are tolerant to PRE and POST applications of dicamba. The development of auxin resistant crops was in response to weed species resistant to glyphosate and other herbicides. Research was conducted to examine herbicides applied to dicamba and glyphosate resistant cotton to at eight different time points in a 24-hr period, ranging from 1-hr prior to sunrise to midnight to determine the effect of herbicide application timing on broadleaf weed control. Herbicides included glyphosate, dicamba, and glyphosate plus dicamba. Visual ratings of weed control were evaluated at 7, 14, 21, and 28 d after treatment (DAT). Efficacy for all herbicide treatments was affected by application timing, with the noon to 1-hr prior to sunset applications exhibiting the greatest control of sicklepod (Senna obtusifolia L.), pitted morningglory (Ipomoea lacunosa L.), and prickly sida (Sida spinosa L.). Lowest levels of control were observed during night applications and greatest at daylight applications, resulting in greater overall control. Sicklepod ranged between 49% at lowest control (12:00AM) to 99% (12:00PM), morningglory ranged between 38 to 99%, and prickly sida between 41 to 96%. In order to quantify some of these results, fluorometer data was taken to measure the effect time of application had on efficiency of the photosystem. Of the many response variables generated using OJIP fluorescence, plant stress indicators were observed greater at a noon time application than at a fully dark adapted pre-dawn application.

Evaluation of Active Ingredient and Application Timing on Chinese Tallow (*Triadica sebifera*) and Callery Pear (*Pyrus calleryana*) by Hack-and-squirt. Hayden Quick*[1], John D. Byrd, Jr.[1], David Russell[2]; [1]Mississippi State University, Mississippi State, MS, [2]Auburn University, Madison, AL (239)

Herbicide active ingredients and seasonal application control were evaluated for Chinese tallow (*Triadica sebifera*) and Callery pear (*Pyrus calleryana*) at two locations per species in Mississippi starting in 2019. Eight factorially arranged treatments (4x8) in a randomized complete block design with four reps were applied winter, spring, summer, and fall by one hack and one squirt per three inches diameter at breast height. All herbicides were undiluted nor was surfactant used with treatments. Leaf necrosis was evaluated up to six months after herbicide treatment (MAT). Herbicide treatments that resulted in the greatest necrosis of Chinese tallow at 6 MAT included isopropylamine salt of imazapyr (Polaris AC Complete), potassium salt of aminocyclopyrachlor (Method 240SL) at 1 ml per hack and choline salt of triclopyr (Vastlan) at 0.5 ml per hack. Isopropylamine and dimethylamine salt of glyphosate (Roundup Pro and Accord XRTII), triethylamine salt and butoxyethyl ester of triclopyr (Garlon 3A and Triclopyr 4) at 1 ml per hack and triclopyr acid (Trycera) at 0.5 ml per hack failed to provide satisfactory control. The 6 MAT evaluation of the winter application to Callery pear showed Method 240SL the best overall treatment, whereas the spring application showed similar control across all treatments. Six MAT ratings for summer and fall applications were inconclusive, but all treatments will be rated for leaf out in spring. Variance in data was analyzed in SAS and means separated by Fisher's LSD (a=0.05). Each season's ratings will be carried out every six months for a two-year study period.

Glyphosate Plus Dicamba Efficacy as Influenced by Spray Nozzle Design and Weed Density. Madison D. Kramer*[1], Zach Perry[2], Travis Legleiter[3]; [1]University of Kentucky, Lynn, IN, [2]University of Kentucky, Paducah, KY, [3]University of Kentucky, Princeton, KY (240)

Dicamba injury to sensitive soybean and other broadleaf crops due to drift is a major issue and label restrictions have been created to mitigate dicamba drift. One restriction is the mandated use of low drift nozzles to spray dicamba, these nozzles produce very coarse to ultra-coarse droplets and minimize the production of driftable fines. Experiments were conducted during the summer of 2018 and 2019 at the University of Kentucky to evaluate herbicide coverage, deposition, and efficacy on *Eleusine indica* and *Amanarthus rudis*. Specifically, looking at the influence of spray nozzle design and weed density. Dicamba plus glyphosate was applied to 5 to 10 cm tall weeds with a Turbo TeeJet (TT11005) nozzle and two drift reduction nozzles approved for dicamba applications: Turbo TeeJet Induction (TTI11005) and Pentatir Ultra Lo-Drift (ULD12005). Weed densities were categorized into different levels and established in a 0.25 m^2 quadrant prior to post application. Fluorescent dye (PTSA) and pink foam marker dye were added to the spray solution to evaluate deposition on target leaf surfaces within the soybean canopy and evaluate coverage on Kromekote spray cards, respectively. Applications were made with an ATV traveling at 16 kph with an output of 140 L/ha^{-1}. The percentage of coverage and depositions per cm^2 was less for the two drift reduction nozzles as compared to the Turbo TeeJet. Deposition of spray solution on to targeted weeds was not different despite differences observed on the Kromekote cards. *Amaranthus rudis* control observed 21 days after treatment was reduced by increased *Amaranthus rudis* density, as well as by the interaction of high Amarnahtus rudis density and the Turbo TeeJet Induction nozzle. Although, *Eluesine indica* control was similar among the different nozzle types and weed density levels. The results from this research has shown that drift reduction nozzles and weed density may not reduce herbicide efficacy onto *Eleusine indica* due to spray solution deposition being equivalent across nozzle types used in this study, but can potentially affect herbicide efficacy on *Amanarthus rudis.*

Mechanism of the Exclusive Reliance on *ALS1* and *ALS3* in the Evolution of Herbicide Resistance in Monochoria (*Monochoria vaginalis*). Shinji Tanigaki*; Kyoto University, Kyoto, Japan (241)

Weed resistance to acetolactate synthase (ALS) inhibitors is often caused by a non-synonymous nucleotide substitution in a single copy of *ALS* gene. *Monochoria vaginalis*, a noxious weed in rice paddy fields, possesses five *ALS* loci, where all the genes encoded are transcribed at least in seedlings. Previous studies on multiple *M. vaginalis* populations identified resistance-conferring mutations exclusively in *ALS1* or *ALS3*, suggesting the existence of a mechanism for the exclusive reliance on *ALS1* and *ALS3* in the evolution of ALS inhibitor resistance in *M. vaginalis*. In this study, we collected 98 suspected resistant accessions of *M. vaginalis* across Japan. Decreased sensitivity to an ALS inhibitor was observed in 66 out of the 98 accessions. Resistance-conferring mutations were found in either *ALS1* or *ALS3* in almost all the resistant accessions. A conserved frameshift mutation resulting in non-functional form of ALS was observed in *ALS4* of all the accessions and in *ALS5* of seven accessions. Next, we compared the enzyme function encoded by the putative functional allele of each *ALS* gene. *Arabidopsis thaliana* lines transformed with the respective *ALS* genes artificially mutagenized to carry Pro197Ser mutation showed similar resistance level when the transcript levels of the transgene were similar. In line with this observation, no significant difference in enzyme activities was observed among the recombinant proteins of each ALS expressed in *E. coli*. On the other hand, RNA-seq analysis revealed that transcript accumulations of *ALS1* and *ALS3* overwhelmed those of the other *ALS* genes. Altogether, our study indicates that the exclusive observations of resistance-conferring mutations in *ALS1* and *ALS3* in Japanese populations of *M. vaginalis* are caused by the higher transcriptions of these genes and by the dominance of functional alleles in these genes.

The Influence of Adjuvants on Tolpyralate Efficacy. Nicole M. Langdon*[1], Peter H. Sikkema[1], Darren E. Robinson[1], Alan J. Raedar[2], David C. Hooker[1]; [1]University of Guelph, Ridgetown, ON, Canada, [2]ISK Biosciences Inc., Concord, OH (242)

Tolpyralate is a new benzoylpyrazole, 4-hydroxyphenyl-pyruvate dioxygenase inhibitor, registered for use in corn, recommended in a tankmix with atrazine and the adjuvants methylated seed oil (MSO) concentrate plus an ammonium nitrogen fertilizer such as UAN. Since 97% of the corn acreage in Eastern Canada is seeded to Roundup Ready® hybrids, the common use pattern for tolpyralate + atrazine will be tankmixed with glyphosate. Two field studies were completed, on two problem weeds in Ontario: glyphosate-resistant (GR) Canada fleabane and waterhemp to determine if an additional adjuvant is required when tolpyralate plus atrazine is tank-mixed with glyphosate. All studies were conducted over a two-year period (2018-19) on farms in southwestern Ontario with confirmed multiple-herbicide-resistant populations. At 4 WAA, the addition of glyphosate to tolpyralate + atrazine increased control of GR Canada fleabane and waterhemp by 18 and 10%, respectively. In the presence of glyphosate, the addition of MSO to tolpyralate + atrazine increased control of GR waterhemp 9%, however, no increase was observed from the addition of additional adjuvants for GR Canada fleabane control. At 8 WAA, all treatment provided >91% control of GR waterhemp and >84% control of GR Canada fleabane. In conclusion, the field studies found that that the adjuvant system in Roundup Weathermax® plays a role in herbicidal enhancement of tolpyralate plus atrazine for the control of GR waterhemp and Canada fleabane.

Overwinter Survival of Johnsongrass (*Sorghum halepense*) Rhizomes in Nebraska and Kansas. Samantha D. Isaacson*, Amit J. Jhala, John Lindquist; University of Nebraska-Lincoln, Lincoln, NE (243)

Johnsongrass (*Sorghum halepense*), can reproduce asexually through its rhizomes. Johnsongrass can be difficult to control and many attributes its hardiness to its rhizomes. But little is known about how well these rhizomes survive in Midwestern states. This experiment aimed to understand how well rhizomes survive in Nebraska and Kansas. Rhizomes were collected from six different populations from Nebraska and Kansas in early November and partitioned into experimental units. Each experimental unit was composed of fifteen nodes. In a randomized complete block design, the experimental units were randomly allocated to test the fresh viability of the rhizomes, the overwinter survival of the rhizomes in Lincoln, NE and Manhattan, KS, and the summer viability in Lincoln and Manhattan. In order to test fresh viability, the rhizomes were planted in a greenhouse and emergence were recorded. Overwinter survival and summer survival were tested in both states by planting rhizomes at two depths, four and eight inches, and being removed in April and August respectively. There was a steep drop off in viability in both Nebraska and Kansas from November to April, and a further drop off in viability from April to August. Averaging over 2018 and 2019, 31.8% of the nodes were viable in November. This dramatically dropped off to only 1.9% by April and was significantly reduced to 0.38% by August. In conclusion, the viability of rhizomes in Nebraska and Kansas are dramatically reduced by harsh winters and further reduced in the summer months.

The Continued Fight Against Glyphosate Resistant Horseweed (*Erigeron canadensis* (L.)). Francois Tardif[1], Emily L. Priester*[2], Clarence Swanton[3], Eric R. Page[4]; [1]University of Guelph, Guelph, ON, Canada, [2]University of Guelph, Tillsonburg, ON, Canada, [3]University of Guelph, Guelph, AZ, Canada, [4]Agriculture and Agri-Food Canada, Harrow, ON, Canada (244)

The last two decades have been marked by a rise in glyphosate resistant weeds worldwide. One troublesome weed, horseweed, can cause great declines in crop yields and is very difficult to manage when resistant to glyphosate. This resistance has occurred through target site and non-target site resistance (NTSR) mechanisms. However, it has been proposed that the main mechanism of resistance in horseweed is vacuolar sequestration. Glycine is an analog of glyphosate that has been shown to act as a competitive inhibitor of glyphosate sequestration. This provided an opportunity to determine the possibility of reducing vacuolar uptake of glyphosate in this particular weed with the use of glycine. The objective of this research was to better understand the resistance mechanisms within horseweed. To do so, a hydroponic system was developed to allow for easy uptake of glycine and glyphosate into the plants. The hypothesis was that previously determined glyphosate resistant horseweed would become susceptible in the presence of a glyphosate plus glycine treatment. Interestingly enough, there was an antagonistic effect from the addition of glycine to the glyphosate treatment. The resistant horseweed showed visual signs of having a greater level of resistance when glycine was added to the glyphosate treatment. More research is needed to fully understand the reason behind this occurrence, however a better understanding of how horseweed operates at the cellular level was achieved.

Cucumber Tolerance to Glufosinate At-planting. Taylor M. Randell*, Jenna C. Vance, A Stanley Culpepper; University of Georgia, Tifton, GA (245)

In 2017, over 13% of the nation's fresh-market cucumbers were produced in Georgia, noting a 52% increase in total hectares from 2012. Current herbicide options for preplant and preemergence use in bareground cucumber production are limited, enticing academic, industry, and USDA partners to search for new options. Glufosinate could provide burndown control of troublesome weeds before or at planting, however its potential for residual activity harmful to cucumber within intensively managed vegetable fields is not well understood. Four studies evaluated the tolerance of transplant cucumber to glufosinate preplant and another four studies determined the tolerance of seeded cucumber to glufosinate preemergence during 2017 and 2018. Application rate (330, 660, 980, and 1,640 g ai ha^{-1}) and influence of overhead irrigation (0.75 cm) a day following glufosinate application was evaluated in both production systems while the influence of interval between application and planting (7, 4, and 1 d) was also determined for transplants. For seeded cucumber, glufosinate applied immediately after seeding visually injured cucumber 8% or less on sandy, low organic matter soils. Vine lengths were only reduced 7% at one of four locations at the highest rate, and implementing overhead irrigation eliminated reductions in vine growth. Early-season fresh weight biomass, early-season yield, and season-total yields were not impacted by glufosinate. For transplanted cucumber, glufosinate applied preplant resulted in 13 to 52% visual

injury. Cucumber vine lengths were reduced 11 to 33% with the three highest rates of glufosinate, and biomass was reduced 36 to 55% with the two highest rates. Early-season yields (harvests 1-4) were reduced 31 to 60% at glufosinate rates of 660 to 1,640 g ha^{-1}, while total yields (13 harvests) were reduced 18 to 46% at the same rates. Implementing overhead irrigation following glufosinate but prior to planting reduced visual injury 38 to 62%, and with the exception of the highest application rate, reductions in vine length, biomass and yield were eliminated. Furthermore, extending the interval between glufosinate application and planting to 7 d was only beneficial at one of two locations. Glufosinate can be used effectively and safely in seeded production while more research is needed in transplant production focusing on irrigation amount and interval between applications and planting.

Impacts of Glyphosate on Citrus Health and Productivity. Biwek Gairhe*, Ramdas Kanissery; University of Florida, Immokalee, FL (246)

Extensive use of glyphosate as a post-emergent weed management 'tool' in Florida citrus groves has drawn increasing concerns about its unintended effects on citrus. Major concerns related to glyphosate use in citrus are its possible impacts on the health and productivity of citrus trees. Hence, the current study was undertaken with objectives to decipher the effects of glyphosate persistence on citrus plant vigor, root health and its yield. Field and lab experiments were conducted at Southwest Florida Research and Education Center, Immokalee, FL. The experimental design was a randomized complete block design (RCBD) with four replications for field studies and a completely randomized design (CRD) with three replications for lab studies. To understand the effects of glyphosate on citrus yield and root health, three different rates of glyphosate (low, medium and high at 0.75, 1.875, and 3.75 pounds acid equivalents of a.i. per acre, respectively) were tested. Water was sprayed in untreated control plots. Subsequent to the application, fruit drop was quantified, and fruit detachment force was recorded during the experiment at pre-determined intervals. Root development was measured using root imaging techniques in minirhizotron tubes. Visual evaluations of glyphosate phytotoxicity symptoms on plants were also recorded. Leaf abscission in response to increasing glyphosate dosages was assessed utilizing ELISA plate method. Results suggest that glyphosate application can significantly affect the fruit detachment force and leaf abscission in citrus. However, no significant effect was observed on the fruit drop, root development, and visual plant injury symptoms.

Young Peanut Physiological Response to Flumioxazin Applications Across Multiple Planting Dates and Seed Vigors. Nicholas L. Hurdle*[1], Timothy L. Grey[2], Eric P. Prostko[2], Walter S. Monfort[2], Cristiane Pilon[2]; [1]University of Georgia, Collierville, TN, [2]University of Georgia, Tifton, GA (247)

Georgia is responsible for over 50% of the United States' peanut (*Arachis hypogaea* L.) production. It is essential for growers to manage weeds in order to maintain this high production. One method growers may use is chemical control, including the use of PRE herbicides. Numerous herbicides are registered for use in peanut, but specific PRE herbicides include pendimethalin, diclosulam, and flumioxazin. A peanuts emerge, it is inevitable for the peanut to contact these PRE herbicides. A study was performed in Ty Ty and Plains, Georgia to record the physiological effects of emerging peanuts as the plants contact these PRE herbicides. A 3x2 factorial RCBD utilizing 3 herbicides and 2 seed germination rates with 4 replications were studied in 2018 and 2019. Planting dates were in early April, mid-April, and early May for each year. Treatments included diclosulam at 27 g ai ha^{-1} PRE, flumioxazin at 107 g ai ha^{-1} PRE, and a nontreated control. Physiological measures included efficiency of photosystem II, photosynthetic rate, and electron transport using a Li-COR 6800 for measurement recording. Data collected also included stand counts and plant diameters. Data was analyzed separately by location using Fisher's Protected LSD. The 2018 season noted minor differences, while the 2019 season reported numerous treatment effects. Differences noted included flumioxazin treated plants having a less efficient PSII at the first measure of plant date 3 in Plains for the 2019 season. Differences were also noted in Ty Ty with the first and last measure of plant date 2, as well as all measurements in plant date 2 in Plains. Plains also had treatment differences during plant date 1 at the first and last measurement. Though numerous differences were recorded, no trend was noted in either year, as the injury was transient and did not affect yield.

Impact of Droplet Size and Carrier Volume on Soybean (*Glycine max*) Harvest Aid Efficacy.
Steven D. Hall*[1], Darrin M. Dodds[2], Greg R. Kruger[3], Jon T. Irby[2], Jacob P. McNeal[2], Lucas X. Franca[2], John J. Williams[2], Bradley J. Norris[2], William J. Rutland[1]; [1]Mississippi State University, Starkville, MS, [2]Mississippi State University, Mississippi State, MS, [3]University of Nebraska-Lincoln, North Platte, NE (248)

An experiment was conducted in 2019 to evaluate the effect of carrier volume and spray droplet size have on the efficacy of soybean (*Glycine max*) harvest aids. This experiment was conducted in Starkville and Brooksville, Mississippi. Eight row (7.7m x 12.2m) plots were planted with ASGRO 46X6 soybeans at a seeding rate of 321,237 seed ha^{-1}. Harvest aid applications were made when 65% mature pods were present with a Capstan® Pinpoint Pulse-Width Modulation (PWM) sprayer on a high-clearance Bowman MudMaster® at a ground speed of 14.5 kilometers $hour^{-1}$. The experiment utilized two carrier volumes (47 and 187 L ha^{-1}) and three droplet sizes (200, 500, and 800µm). Harvest aids included paraquat (Gramoxone® SL 2.0) at 3.88 kg ai ha^{-1} saflufenacil (Sharpen®) at 0.04 kg ai ha^{-1} and sodium chlorate (Defol 5®) at 2.85 kg ai ha^{-1}. Visual ratings were taken at 3,7,10, and 14 days after application and included percent defoliation, desiccation, and green leaves. All the ratings were based off the untreated check in each replication. The center two rows were harvested with a combine specialized for small plot research and grain moisture checked for each plot. The experimental design was a randomized complete block that included 4 replications. These data were subjected to analysis of variance using the PROC MIXED procedure in SAS v9.4. Means were separated using Fisher's Protected LSD with an alpha value of 0.05. Green leaves at 10 days after application were impacted by an interaction between carrier volume and harvest aid. Saflufenacil at the lower carrier volume produced 25% green leaves left on the plant. At 14 days after application, the application of saflufenacil resulted in 11% green leaves. These percentages were statically greater than were from other treatments but did not translate into yield reduction. However, soybeans to which saflufenacil was applied resulted in greater grain moisture percentage. However, observed percent grain moisture was still under the desired moisture level above which a reduction in price would be received from the elevator

Effect of Herbicides Applied at First Visible Female Inflorescence on Palmer Amaranth (*Amaranthus palmeri*) Fecundity and Seed Viability. Eric B. Scruggs*, Michael L. Flessner; Virginia Tech, Blacksburg, VA (249)

Weeds have reduced crop yields and provided management challenges to growers since the beginning of agriculture. The development of herbicide resistant and multiple-resistant populations has further complicated these challenges. In particular, Palmer amaranth (*Amaranthus palmeri* S.) has been ranked the most troublesome weed due to its aggressive growth, prolific seed production, and resistance to many herbicides. Effective control at a size greater than 10 cm is difficult yet season-long control is necessary to reduce additions to the soil seedbank. With the goal of mitigating herbicide resistance, studies were initiated to determine the effects of herbicide application at first female inflorescence on weed control, seed production, and viability. Field studies in VA in 2019 utilized 2 randomized complete block designs with four replications split by soybean variety (Enlist and Xtend). Treatments consisted of: glyphosate, 2,4-D (Enlist), 2,4-D + glyphosate (Enlist), glufosinate (Enlist), glufosinate + glyphosate (Enlist), 2,4-D + glufosinate (Enlist), 2,4-D + glufosinate + glyphosate (Enlist), dicamba (Xtend), dicamba + glyphosate (Xtend), dicamba + glufosinate (Xtend), and dicamba + glufosinate + glyphosate (Xtend). Treatments were used at labeled rates and included adjuvants and nozzles as noted on product labels. Palmer amaranth populations for these studies were glyphosate-resistant. In each plot, 10 Palmer amaranth plants were flagged at first visible female inflorescence directly prior to treatment application and all other weeds were removed. Data collected included visible control assessed on a 0 (no control) to 100 (plant death) scale four weeks after treatment (WAT), seed production of surviving flagged plants, and soybean yield. All data were subjected to ANOVA and subsequent means separation using Fisher's Protected LSD (a=0.05). Where necessary, data were transformed to improve normality and back transformed data were presented. Palmer amaranth control was greatest from 2,4-D + glyphosate + glufosinate (94%), 2,4-D + glufosinate (95%), glufosinate + glyphosate (88%), and glufosinate alone (86%) in Enlist soybeans, 4 WAT. 2,4-D applied alone resulted in 62% control and glyphosate alone resulted in 16% control. Similar results were seen in the Xtend treatments, with dicamba + glufosinate + glyphosate (94%), dicamba + glufosinate (93%), and dicamba + glyphosate (87%) performing best. Dicamba alone resulted in 72% control and glyphosate alone resulted in 9% control. All treatments, including glyphosate, reduced seed production compared to the nontreated in Enlist soybeans. Glyphosate alone reduced seed production 66% and all other treatments reduced seed production 95 to 99.8%. In Xtend soybeans, all treatments besides glyphosate reduced seed production 98 to 99%. There were no differences in yield among treatments. These studies indicate the efficacy of glufosinate, dicamba, and 2,4-D applied alone and in mixtures in reducing Palmer amaranth seed production when applied at first visible female inflorescence. Future research will examine cumulative seedling emergence and seed viability from survivors of these treatments. Future research should also investigate delayed applications of glufosinate following auxin herbicides on seed production and alternative timings.

Utility of Potassium Borate as a Volatility Reduction Agent and its Impact on Weed Control in Xtend™ Crops. Mason C. Castner*, Jason K. Norsworthy, Trenton L. Roberts; University of Arkansas, Fayetteville, AR (250)

Engenia and XtendiMax with VaporGrip are labeled for preemergence and postemergence control of broadleaf weeds in XtendFlex cotton and Roundup Ready 2 Xtend soybean. Despite the efficacy of dicamba on problematic weeds, labeled applications of Engenia and XtendiMax in both cotton and soybean have presented major concerns for off-target movement, primarily to non-dicamba-resistant soybean. To counteract the volatility associated with the new dicamba formulations, potassium tetraborate tetrahydrate (potassium borate) and other foliar nutrients are being applied as additives with dicamba in order to supply essential nutrients to soybean and complimentarily reduce the volatility of dicamba. Field research in 2019 showed that the addition of potassium borate to dicamba significantly lowered the dicamba volatility. Subsequently, it was unknown whether addition of potassium borate to dicamba would negatively affect weed control. To further investigate the effects of potassium borate on weed control, a greenhouse experiment was conducted in Fayetteville, Arkansas. Trays filled with potting mix were seeded with Palmer amaranth (*Amaranthus palmeri*) and prickly sida (*Sida spinosa*), which were thinned to 10 plants per species per tray soon after emergence. The experiment was set up as a three-factor, randomized complete block design with three replications. The first factor consisted of three dicamba formulations (XtendiMax, Engenia, and the diglycolamine salt of dicamba) combined with two rates (140 and 280 g ae ha^{-1}) with a 1x rate being dicamba at 560 g ae ha^{-1}. The third factor was with or without the addition of potassium borate. The only significance observed was the rate of dicamba applied, with weeds receiving dicamba at 280 g ae ha^{-1} displaying increased control over those treated with 140 g ae ha^{-1}, regardless of weed species. Despite few numerical differences with respect to formulation, the addition of potassium borate did not reduce efficacy with either weed species.

HPPD Tolerant Cotton Response, Weed Management, and Tank Mix Partners with Isoxaflutole. Delaney C. Foster*[1], Peter A. Dotray[2], Corey Thompson[3], Greg Baldwin[4], Frederick Moore[5]; [1]Texas Tech University, Lubbock, TX, [2]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX, [3]BASF, Abernathy, TX, [4]BASF, Research Triangle Park, NC, [5]BASF, Lubbock, TX (251)

The increase in number of herbicide resistant weeds threatens Texas cotton production and profitability, forcing producers to use multiple herbicide modes of action to manage weeds. *P*-hydroxyphenylpyruvate dioxygenase (HPPD) inhibitors are a relatively new class of herbicide chemistry although first available for use in the 1980's. While current varieties do not tolerate HPPD inhibitors, BASF Corporation has developed HPPD-tolerant cotton that will allow growers to use isoxaflutole in future weed management programs. Utilizing multiple modes of action that include the use of soil residual herbicides will increase weed management options and help steward old and new herbicide technologies. In 2019, field experiments were conducted to examine crop response and weed control when incorporating isoxaflutole into local season-long weed management programs as well as to evaluate weed control following isoxaflutole applied alone and with a number of different tank mix partners. There were two locations examining crop response (Lubbock and New Deal, TX), one location examining season long weed control (Halfway, TX), and ten locations examining isoxaflutole tank mix partners (Arkansas, Georgia, Mississippi, Oklahoma, Tennessee, and Texas). When examining cotton response to isoxaflutole, minimal herbicide injury (<15%) was observed and cotton lint yields at both locations were similar to the non-treated weed-free control. Season-long weed control when incorporating isoxaflutole into local weed management programs was equal to or better than the current local standard herbicide program which did not include isoxaflutole. Tank-mixing isoxaflutole with other preemergence herbicide modes of action increased residual weed control regardless of herbicide used. Overall, the opportunity to use isoxaflutole in cotton will improve season-long control of Palmer amaranth when used as part of an overall weed management program.

Control of Glyphosate/Glufosinate-Resistant Volunteer Corn in Corn Resistant to Aryloxyphenoxypropionates. Adam Striegel*[1], Stevan Knezevic[2], Nevin Lawrence[3], Jeffery Krumm[4], Gary Hein[1], Amit J. Jhala[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Concord, NE, [3]University of Nebraska-Lincoln, Scottsbluff, NE, [4]Corteva Agriscience, Hastings, NE (252)

Corn-on-corn production systems are common in highly productive irrigated fields in southcentral Nebraska which can create management issues with volunteer corn in corn fields. Enlist is a new trait conferring resistance to 2,4-D choline, glyphosate, and the aryloxyphenoxypropionate (FOPs) chemical family in the acetyl CoA carboxylase (ACCase) inhibitor site of action group, which is commonly integrated into glufosinate-resistant germplasm. The objectives of this study were to (1) to evaluate ACCase-inhibiting herbicides for control of glyphosate/glufosinate-resistant volunteer corn in Enlist corn and (2) to evaluate effect of timing of applying ACCase-inhibiting herbicides (early POST versus late POST) on volunteer corn control, Enlist corn injury, and yield. Field experiments were conducted in 2018 and 2019 at South Central Agricultural Laboratory in Clay County, Nebraska. Glyphosate/glufosinate-resistant corn grown and harvested the year prior was cross-planted to mimic volunteer corn at 49,000 seeds ha^{-1}. After a week, Enlist corn was planted at 91,000 seeds ha^{-1}. Application timing of fluazifop, quizalofop, and fluazifop/fenoxaprop had no effect on crop injury, crop yield, and provided 97 to 99% control of glyphosate/glufosinate-resistant volunteer corn at 28 d after treatment (DAT). Cyclohexanediones (clethodim and sethoxydim) and phenylpyrazolin (pinoxaden) provided 65 to 98% control of volunteer corn at 28 DAT; however, resulted in 63 to 99% Enlist corn injury and 68 to 98% yield reduction. Orthogonal contrast analysis revealed no difference between early POST versus late POST application of FOPs for volunteer corn control, Enlist corn injury, or yield. While all aryloxyphenoxypropionate products resulted in >94% control of volunteer corn with no associated Enlist corn injury or yield loss, quizalofop is the only labeled product as of 2020 for control of volunteer corn in Enlist corn and can be recommended to producers.

Understanding Interspecific Hybridization Between *Sorghum bicolor* and its Weedy Congener *S. halepense*. Cynthia Sias*, Blake L. Young, Daniel Hathcoat, George Hodnett, William Rooney, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (253)

The potential for gene flow between cultivated species and their weedy relatives poses agronomic and environmental concerns, particularly when there are opportunities for the transfer of adaptive or agronomic traits such as herbicide resistance into the weedy forms. One of the most widely cultivated crops in Texas, *Sorghum bicolor*, is a prime example of a crop that has a weedy relative, *S. halepense*, capable of exchanging genetic information. Previous findings have shown that *S.*

bicolor (diploid; 2n=2X=20) and *S. halepense* (2n=4X=40) can hybridize under natural field conditions, but little is known as to how the frequency of hybridization is affected by a) sorghum genotype, b) cytoplasmic male sterility type, and c) pollen competition. Field experiments were conducted to determine the frequency of hybridization across 12 different *S. bicolor* genetic backgrounds and three male sterility types (A1, A2, A3), with a natural population of *S. halepense* serving as the pollinator parent. Two experiments were conducted in parallel where male fertile and male sterile versions of the 12 genotypes were compared side-by-side to evaluate the impact of pollen competition on the frequency of hybridization. Results showed that the frequency of hybridization was greatly influenced by *S. bicolor* genotype and there was a significant genotype x cytoplasmic male sterility type interaction. Further, pollen competition greatly reduced hybridization frequencies across *S. bicolor* genotypes. Findings provide insights on hybridization frequencies at field conditions and help mitigate gene flow through selection of *S. bicolor* genotypes with less risk for hybridization.

3MT™ Ph.D. Program

A Target Site Mutation Confers Protoporphyrinogen Oxidase (PPO)-resistance in Wild Poinsettia (*Euphorbia heterophylla* L.). Rafael R. Mendes*[1], Hudson K. Takano[2], Fernando Storniolo Adegas[3], Rubem S. Oliveira Jr.[1], Todd A. Gaines[2], Franck E. Dayan[2]; [1]Maringa State University, Maringa, Brazil, [2]Colorado State University, Fort Collins, CO, [3]Embrapa Soybean, Londrina, Brazil (254)

Wild poinsettia (*Euphorbia heterophylla* L.) is a troublesome broadleaf weed in South America, especially in grain production areas. This species has been under strong herbicide selection pressure since the 1990s, including protoporphyrinogen oxidase (PPO)-inhibiting herbicides. This research aimed to elucidate the basis for resistance to PPO-inhibiting herbicides in a wild poinsettia population (R_{PPO}) from Parana State, Brazil. Postemergence dose response experiments confirmed cross-resistance to lactofen (47.7-fold), saflufenacil (8.6-fold), pyraflufen-ethyl (3.5-fold), and flumioxazin (2-fold). Twenty-four hours after lactofen treatment (120 g ha^{-1}), R_{PPO} accumulated 27 times less protoporphyrin, as well as produced 4.5 - 5 times less reactive oxygen species, compared to susceptible (S_{PPO}) plants. Application of 1000 g ha^{-1} malathion 24 h prior to lactofen (120 g ha^{-1}) did not revert the resistance in R_{PPO}, suggesting that herbicide metabolism by P450 monooxygenases is not involved. The sequences of wild poinsettia *PPO1* and *PPO2* genes from R_{PPO} and S_{PPO} populations were analyzed and the expression of these genes were compared to the reference acetolactate synthase (*ALS*) gene. While there were no differences in *PPO1* and *PPO2* expression from R- and S_{PPO} plants, a single nucleotide polymorphism (SNP) resulting in the R128L amino acid substitution was detected in the *PPO2* sequence. This amino acid is located in an important and conserved region of *PPO2* where the mutation changes the catalytic domain of the herbicide-enzyme binding. Our findings confirmed that a target site mutation at *PPO2* gene (R128L) confers cross-resistance to PPO-inhibiting herbicides in wild poinsettia.

Shedding Light on the Power of Plant Competition. Nicole Berardi*[1], Clarence Swanton[2]; [1]University of Guelph, Guelph, ON, Canada, [2]University of Guelph, Guelph, AZ, Canada (255)

Changes in light quality induced by the presence of neighbouring weeds are an important mechanism of plant competition affecting crop plants during the early stages of seedling development. Alteration of the light environment is recognized via changes in the red/far-red light ratio (R/FR), in which a reduction in R/FR is induced by light that is reflected upwards off weeds. Recognition of a reduced R/FR elicits physiological stress responses within the crop plant characterized by increased reactive oxygen species (ROS) production and subsequent modification of antioxidant capacity to regulate ROS levels. The resulting physiological responses due to the presence of neighbouring weeds are hypothesized to be the cause of significant yield losses during early season weed competition. To explore the associated stress and antioxidant responses to weed competition, *Arabidopsis* and maize were studied under three light environments, a high R/FR (weed-free, ~1.8) environment, and two low R/FR environments (biologically weedy and artificial FR, ~0.3). Results indicate that in response to the low R/FR light environments levels of ascorbate were significantly decreased when compared with the weed-free light environment in both *Arabidopsis* and maize. Fluctuations in associated antioxidant regenerating enzymes were also observed in both species. These results demonstrate the importance of elucidating the molecular basis of weed-crop competition. Further identification of these responses and associated genes would not only provide important insights into the molecular basis of weed-crop competition but may also provide targets for improving weed stress tolerance in crop plants.

Evolved Resistance to Herbicides in Palmer Amaranth Accessions Collected in the North Carolina Coastal Plain. Denis J. Mahoney*; North Carolina State University, Clayton, NC (256)

Paper withdrawn

Sweetpotato Tolerance to Indaziflam. Stephen C. Smith*[1], Katherine M. Jennings[1], David W. Monks[1], Michael R. Schwarz[2], David L. Jordan[1], Chris Reberg-Horton[1]; [1]North Carolina State University, Raleigh, NC, [2]Affiliation Not Specified, Raleigh, NC (257)

Indaziflam is a cellulose biosynthesis inhibiting herbicide registered for use in grape, citrus, pome and stone fruit and tree nuts. Although not registered in sweetpotato, it is effective in controlling many of the most common weeds found in sweetpotato including Palmer amaranth, common purslane, Florida pusley, and certain morningglory species. However, sweetpotato tolerance to indaziflam is not known. Thus, field studies were conducted in commercial sweetpotato fields and at the Horticultural Crops Research Station in Clinton, NC in 2018 and 2019 to determine response of 'Covington" sweetpotato to indaziflam applied PREPLANT, or POST over-the-top 1 or 2 wk after transplanting at 0 (nontreated check), 29, 44, 58, or 73 g ai ha^{-1}. Indaziflam POST caused transient foliar injury to sweetpotato. At 4 WAP, indaziflam (58 or 73 g ai ha^{-1}) applied POST 2 WAP caused the greatest stunting (56 and 63% respectively). By 8 WAP <15% stunting was observed for all treatments. Marketable (jumbo plus no.1) and no. 1 yield were reduced by indaziflam applied POST 2 WAP. Indaziflam reduced storage root length to width ratio by 9%.

Application Timing on Control of *Echinochloa*. Clay M. Perkins*[1], Larry Steckel[1], Thomas C. Mueller[2], Marshall Hay[3], Ethan T. Parker[3]; [1]University of Tennessee, Jackson, TN, [2]University of Tennessee, Knoxville, TN, [3]Syngenta, Vero Beach, FL (258)

Junglerice *(Echinochloa colona* L.) and barnyardgrass *(Echinochloa crus-galli)* populations have progressively become more of a pest in soybeans and cotton in recent years across the Mid-South and especially in Tennessee. The initial take was glyphosate resistance was leading the struggles on controlling these populations. However, recent research shows that tank mixing glyphosate and/or clethodim with dicamba was also contributing to the continuous failures in control. Growers and retailers have increasingly reported poor control of junglerice with a tank mixture of dicamba plus glyphosate. Therefore, research was initiated that evaluated split applications of glyphosate and dicamba as well as application timing with a sequential application of 24 and 72 hours. Greenhouse studies were conducted across two populations collected from fall 2018 in Tennessee. Herbicide treatments included a non-treated check, glyphosate, glyphosate + dicamba, glyphosate fb dicamba (24 hr.), dicamba fb glyphosate (24 hr.), glyphosate fb dicamba (72 hr.), and dicamba fb glyphosate (72 hr.). These treatments were applied in a spray chamber using a TTI 110015 nozzles at 142 L/ha (15 GPA). No drift reduction agent (DRA) will be utilized in dicamba tank mixes to reduce the effect of droplet size on data. Herbicide control of junglerice will be visually assessed on a scale of 0 to 100% where 0 = no injury and 100 = plant death at 28 days after treatment. Biomass will be taken 28 days after treatment. All data will be subjected to an analysis of variance with appropriate mean separation techniques. Initial results indicate that tank mixing dicamba with glyphosate results in roughly 30% less control. Glyphosate alone resulted in 83% control on junglerice. Tank mixing the two resulted in 50% control. No significant difference were observed at the 24 hour sequential timing between the two methods. However, at the 72 hour sequential, dicamba fb glyphosate resulted in 100% control on junglerice. When looking at glyphosate fb dicamba, only 50% control was obtained. This research suggests that dicamba needs to be left out of the tank and these sequential applications of glyphosate need to be utilized when controlling these *Echinochloa* spp. complex. If both Palmer amaranth (*Amaranthus palmeri*) and *Echinochloa* spp. are present in the field, which based on preliminary research in Tennessee that rate is roughly 40% of the time, then spraying dicamba with a residual herbicide product to control Palmer amaranth followed by a glyphosate application at least 72 hours later provides excellent control. Sequential applications are very time consuming as well as an added cost, but it is the best option moving forward to adequately control the two species and especially *Echinochloa.*

Exploring the Impacts of Weeds in Perennial Grain Crops. Eugene P. Law*[1], Matthew R. Ryan[1], Antonio DiTommaso[2]; [1]Cornell University, Ithaca, NY, [2]Cornell University, Dryden, NY (259)

Perennial small grain crops can be used for dual-purpose production of grain and forage while also contributing important ecosystem services such as soil health improvement, water quality protection, and habitat for native fauna. Creating commercially viable production systems for these crops will require understanding weed competition dynamics and developing weed management programs that are effective over the three to five year life of a perennial grain stand. Since 2016 we have conducted a variety of field and greenhouse experiments at Cornell University with two of the most advanced perennial grain cultivars, 'Kernza' intermediate wheatgrass (*Thinopyrum intermedium*) and 'ACE-1' perennial cereal rye (*Secale cereale* x *S. strictum*). These projects have included efforts to characterize weed communities, to understand impacts of post-harvest weed competition, and to begin the process of identifying effective chemical weed control options in these two perennial grain crops. Research outcomes have highlighted the increased complexity of weed ecology and management in perennial systems as well as important differences between perennial grains developed via hybridization versus domestication.

Cover Crops for Suppressing Weeds in Citrus (*Citrus sinensis*) Row-Middles. Ramdas Kanissery[1], Miurel T. Brewer*[2], Davie M. Kadyampakeni[3]; [1]University of Florida, Immokalee, FL, [2]University of Florida, Arcadia, FL, [3]University of Florida, Lake Alfred, FL (260)

Paper withdrawn

Understanding Herbicide Resistance Through the Lens of Epigenetics. Gourav Sharma*, Jacob Barney, Shawn Askew, James Westwood, David Haak, Liqing Zhang, Suzanne Lalibrate; Virginia Tech, Blacksburg, VA (261)

Modern herbicides are the most successful and efficient tool for weed control but due to widespread and repetitive use of few herbicides mode of action, weeds develop herbicide resistance. Herbicide resistance is the result of a powerful human-driven selective pressure on weeds. Today there are 512 unique cases of herbicide resistant weeds globally comprising 262 species. Two general categories of resistance are target site resistance (TSR) and non-target site resistance (NTSR). TSR mechanisms are well understood and arise from a single point mutation in the herbicide target gene, but those involving NTSR are still poorly understood and could result from several mechanisms. NTSR can confer an unpredictable level of resistance that may also affect response to herbicides with different modes of action, including herbicides not yet marketed. The origin and genetic bases for these resistance mechanisms is not known. The field of epigenetics may contribute to understanding NTSR in that it explains how organisms are able to adapt to various abiotic/biotic stresses through non-sequence based modifications of their DNA, such as changes in methylation status or histone assembly. Herbicides and other management practices to control weeds, such as shading and clipping, impose stress on the weeds. Sub-lethal weed management practices could lead to epigenetic modifications that may facilitate evolution of resistance, but the role of epigenetic processes in the evolution of herbicide-resistant weeds is still untested. One of the well-studied epigenetic regulatory mechanisms is DNA methylation, which is the addition of a methyl group to cytosine nucleotides in DNA, which can turns genes on or off. We are working on the model plant *Arabidopsis thaliana,* and the common weed shattercane (*Sorghum bicolor*) to look at changes in DNA methylation patterns due to the sub-lethal dose of herbicides and other common stresses, seeking to understand whether epigenetic changes are shared or unique among stresses. In addition, we are looking at the heritability and stability of the DNA methylation patterns over the course of multiple generations in *Arabidopsis thaliana* when exposed to a sub-lethal dose of herbicide. Thus, this project will elucidate the importance of DNA methylation in weed evolution due to herbicides and other management strategies

Quantifying 2,4-D and Dicamba Dissipation from Plastic Mulch Using Analytical and Bioassay Techniques. Lavesta C. Hand*, Kayla M. Eason, Taylor M. Randell, Timothy L. Grey, A Stanley Culpepper; University of Georgia, Tifton, GA (262)

In plasticulture vegetable production, multiple crops can be produced on a single instillation of plastic mulch. Fumigants and cover crops provide excellent weed control for the first crop, however, herbicides are necessary to prepare for weed-free planting in subsequent crops. Glyphosate and paraquat are the most popular options for growers because they can be removed from mulch with rainfall or irrigation, but weed escapes are becoming common. Research in 2018 and 2019 helped better understand the potential for using 2,4-D or dicamba in these systems. A factorial with treatments arranged in an RCBD with four replications included 3 herbicide options being dicamba plus glyphosate (560 + 1,125 g ae ha^{-1}) and 2,4-D plus glyphosate (1,065 + 1,125 and 2,130 + 2,250 g ae ha^{-1}) applied over mulch at four application intervals of 45, 30, 15, and 1 d before planting (DBP); two non-treated controls were included for comparison. Dissipation was analytically quantified by UPLC/MS along with squash (*Cucurbita pepo* L.) and watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) bioassays. Analytical analysis indicated dicamba concentrations present on plastic mulch at planting were nearly 16 times greater than that of 2,4-D when herbicides were applied 15 to 45 DBP. As a result, dicamba injured squash 12, 65, 75, and 95% when applied 45, 30, 15, or 1 DPB, respectively. Squash widths and fresh weight biomass were similarly reduced when dicamba was applied 1 to 30 DBP. When harvested 30 times, yield losses of 45 to 98% was observed when dicamba was applied within 30 DBP. Averaged over rate, 2,4-D treatments caused 2, 4, 7, and 73% squash injury at the aforementioned application intervals with reductions in squash widths, fresh weight biomass, and yield only noted with applications 1 DBP. Dicamba injured watermelon 13, 39, 42, and 94% while applications of 2,4-D resulted in 1, 2, 4, and 94% injury at the aforementioned application intervals. Vine length response was similar to the injury for dicamba applied 1 to 30 DBP and 2,4-D applied 1 DBP, resulting in significant reductions, while biomass was only reduced when herbicides were applied 1 DBP. Watermelon recovery was remarkable noting yield loss only with 1 DBP treatments. Herbicide option, crop, and rainfall accumulated prior to planting ($\geq$ 11.3 cm, $\geq$ 9.3 cm, $\geq$ 3.7 cm, and 0 cm with applications 45, 30, 15, or 1 DBP, respectively) significantly influenced the outcome.

Fine Tuning Goosegrass (*Eleusine indica*) Control for Northern Bermudagrass. John Brewer*, Jordan M. Craft, Shawn Askew; Virginia Tech, Blacksburg, VA (263)

Within bermudagrass turf systems goosegrass ranks as one of the toughest weeds to control. Since registration in 2013, topramezone has proven to be an effective goosegrass control option in cool-season turfgrass systems and has recently been labeled in bermudagrass. Unfortunately, bermudagrass is very sensitive to topramezone even at one quarter of the labeled rate. This injury is transient in nature and bermudagrass recovers in 2 to 3 weeks. Due to limited post-emergent herbicide options in bermudagrass, it's necessary to evaluate topramezone further to alleviate injury issues. Like many others around the southeast, we at Virginia Tech are evaluating different programs to reduce both severity and duration of this injury. To that end, we began to evaluate programs with topramezone and metribuzin specifically a range of topramezone rates applied with metribuzin to reduce bermudagrass injury while maintaining effective goosegrass control. From 2018 to 2019, a total of 8 bermudagrass tolerance studies and 5 goosegrass control studies were completed to assess topramezone plus metribuzin compared to topramezone alone at various rates. These trials were established at the Turfgrass Research Center and Glade Road Research Facility in Blacksburg, VA. All studies were arranged in a randomized complete block design with 4 replications. Treatments were applied with a CO_2-pressurized sprayer calibrated to deliver 374 L ha^{-1}. Treatments for all studies included topramezone applied at 1.22 g ai ha^{-1}, 3.68 g ai ha^{-1}, and

6.14 g ai ha^{-1} which were mixed with metribuzin applied at 280.2 g ai ha^{-1} and topramezone applied alone at 6.14 g ai ha^{-1} as comparison. All treatments had secondary applications that occurred 3 weeks after initial. The tolerance studies were rated for percent total injury, percent bleaching, and NDVI weekly for 6 weeks with a final rating at 8 weeks. The goosegrass control studies were rated for percent goosegrass cover, percent control, and final plants counts at 1, 2, 4, 6 and 8 weeks after initial application. During all bermudagrass tolerance trials in 2018 and 2019, topramezone applied at 3.68 g ai ha^{-1} plus metribuzin at 280 g ai ha^{-1} injured bermudagrass from 28 to 58% and approximately 50% less than topramezone applied alone (82 to 99% injury). Also bleaching from topramezone applied alone ranged from 76 to 99% while the topramezone and metribuzin combo bleached bermudagrass from 0 to 38%. In 2018 and 2019, topramezone applied at 3.68 g ai ha^{-1} plus metribuzin at 280 g ai ha^{-1} controlled goosegrass more effectively than topramezone alone from initiation until 4 weeks after application, however by the final rating, both treatments controlled goosegrass 96% or greater. Both treatments averaged less than 4 plants m^{-2} remaining in plots by the end of all studies in 2018 and 2019, while the untreated plots averaged 67 and 38 plants m^{-2}, respectively.

Testing Rangeland Drought Resistance in the Presence of Ventenata (*Ventenata dubia*). Marshall Hart*[1], Brian Mealor[2]; [1]University of Wyoming, Sheridan, WY, [2]University of Wyoming, Laramie, WY (264)

Rangelands provide many ecosystem goods and services (EGS), and their ability to provide a stable amount of forage across variable precipitation years is critical for livestock, wildlife, and the many landowners that depend on them for income. Unfortunately, competition from invasive annual grasses may exacerbate drought effects, further reducing perennial forage production. Although invasive annual grasses provide some forage value, extreme variation in productivity has been documented. This leads us to believe that annual grasses would be insufficient as forage during drought compared to perennial grass-dominated systems. However, the opportunity to study this is elusive. Scientists face difficulties when studying highly complex ecosystems, like rangelands, that must be overcome. The unpredictability of drought coupled with the escape risk of studying a highly invasive species makes it difficult to study such relationships with short term experiments in natural settings. We have applied a mesocosm approach to overcome these difficulties and answer the question of whether invasion by annual grasses interacts with drought to reduce perennial grass production below what would be expected in a non-invaded ecosystem. This approach allows greater control over precipitation quantity and timing and makes biological escape less likely while still being able to answer the question of interest. Our approach will hopefully provide answers that can be applied to rangelands where drought and invasion are often co-occurring problems.

The Effect of Low-Dose Dicamba Applications on Snap Bean (*Phaseolus vulgaris*), Lima Bean (*Phaseolus lunatus*) and Southern Cowpea (*Vigna unguiculata*). Hannah E. Wright*[1], Thomas Gray[2], John Shugart[3], A Stanley Culpepper[4]; [1]University of Georgia, Athens, GA, [2]Georgia Department of Agriculture, Atlanta, GA, [3]Georgia Department of Agriculture, Tifton, GA, [4]University of Georgia, Tifton, GA (265)

With a rapid adoption of dicamba cropping systems, an increase in the use of dicamba and a subsequent increase in the occurrence of injury on non-target crops has been observed. Snap beans (*Phaseolus vulgaris* L.), lima beans (*Phaseolus lunatus* L.), and southern cowpeas (*Vigna uniguiculata* (L.) Walp.) are high value crops in Georgia, contributing over $29 million in in farmgate value during 2017. Field studies were conducted in Tifton, GA in 2015 and 2019 to evaluate the effect of low dose dicamba rates on these three crops. This experiment was conducted as a split-plot design with dicamba rate as the whole-plot factor (1/250X, 1/500X, 1/750X, 1/1,000X, 1/1,250X, 1/1,500X, and 0X with the X rate being 560 g ae ha^{-1}) and crop (snap bean, lima bean, and southern cowpea) as the sub-plot factor. Applications were made 19 to 22 d after planting (DAP) with maximum visual injury recorded 10 to 11 d after treatment (DAT). Additionally, ten plant heights and biomass from 1.2 m of row were collected 17 to 21 DAT. Mature fruit were collected from 1.5 m of row at crop maturity and weighed as a measure of yield. Lima bean and cowpea responded similarly with the most injury observed at the 1/250X rate at 38%, down to 12% injury at the 1/1,1500X rate. There was a 9 to 40% reduction in lima bean biomass and cowpea plant heights and biomass from the 1/1,000X and higher rates. Additionally, there was a 26 to 46% reduction in yield for lima bean and cowpea from the 1/250X and 1/500X rates. Snap beans were the most sensitive crop evaluated, with injury of 24 to 50% and height reduction of 20 to 41% from all dicamba rates. There was also a 12 to 44% reduction in snap bean biomass from the 1/1,250X to 1/250X rates and all rates reduced yield 18 to 63%. Leaf and fruit samples from snap beans were collected 17 DAT in 2015 and 7 DAT in 2019 and immediately analyzed for dicamba residues in accordance with Georgia Department of Agriculture standard procedures. No dicamba residues were detected in 2015, however in 2019 dicamba residues ranging from 0.0023 from plants treated with the 1/1,500X rate to 0.0196 PPM from plants treated with the 1/250X rate were detected in leaf samples. No dicamba residues were detected in fruit samples in either year.

Using Linuron to Improve Sweetpotato Production. Levi D. Moore*, Katherine M. Jennings, David W. Monks, Michael D. Boyette, David L. Jordan, Ramon G. Leon; North Carolina State University, Raleigh, NC (266)

Palmer amaranth is the most common and troublesome weed in North Carolina sweetpotato. No POST herbicides are registered for in-row application for Palmer amaranth, requiring weedy escapes to be removed by hand. Thus, field studies were conducted in 2018 and 2019 to evaluate weed management programs with linuron applied POST over-the-top of sweetpotato. Treatments included flumioxazin PREPLANT fb linuron (280, 420, 560, 700, 840 g ai ha^{-1}) with or without *S*-metolachlor (800 g ai ha^{-1}) or oryzalin (840 g ai ha^{-1}) applied 7 d after planting. Two out of the three studies in 2018 were maintained weed-free season long with hand removal. An additional study was conducted in 2019 to evaluate linuron (420, 700 g ai ha^{-1}) with or without *S*-metolachlor (840 g ai ha^{-1}) with or without nonionic surfactant (NIS) (0.5% v/v) for Palmer amaranth control. Increasing the rate of linuron or applying it with *S*-metolachlor or NIS increased sweetpotato injury. When flumioxazin was included, Palmer amaranth did not emerge prior to the POST application. Residual control of Palmer amaranth from linuron was < 30% and did not improve the efficacy of systems including *S*-metolachlor. Combining linuron with *S*-metolachlor decreased sweetpotato yield in the absence of weed competition by up to 28%. Without flumioxazin, linuron plus *S*-metolachlor with or without NIS provided the greatest Palmer amaranth control and sweetpotato yield. Therefore, linuron has greatest potential for use in sweetpotato when Palmer amaranth has emerged prior to an application of *S*-metolachlor.

Adapting Integrated Pest Management for Weeds in Almonds. Steven C. Haring*; University of California, Davis, Davis, CA (267)

I study integrated pest management for weeds in California nut orchards. Integrated pest management is necessary for continued productivity and increased ecological resilience of all cropping systems, and California orchard growers have unique management concerns regarding weed management. Integrated weed management strategies can be difficult to implement in perennial cropping systems in a semi-arid climate and with extreme labor demands. Integrated solutions to these problems require integrated research programs that are sensitive to the needs of the agroecosytem. My research involves understanding the reproductive biology of a perennial weed that is especially problematic in young nut orchards, investigating cover crops as a potential weed management practice, and studying how growers make complex management decisions regarding pesticide use. California is a unique place with unique socio-ecological systems. I hope that my research can use these unique factors to help growers implement integrated weed management programs in order to protect the environment, rural citizens, and eaters.

Characterization of Trifludimoxazin, a New Herbicide for Use in Soybean Production Systems. Nicholas R. Steppig*[1], Bryan G. Young[2]; [1]Purdue University, Lafayette, IN, [2]Purdue University, Brookston, IN (268)

Commercialization of a new herbicide requires, among several other factors, that the active ingredient be safe for use in target crops, as well as effective at controlling troublesome weeds within those cropping systems. Trifludimoxazin is a new PPO-inhibiting herbicide currently being developed by BASF Corporation for preplant use in soybean (*Glycine max*). As part of my PhD research, I have spent the last three years characterizing soybean response to applications of triflidimoxazin when applied prior to planting, in addition to evaluating trifludimoxazin's efficacy on major weeds in soybean production in the state of Indiana. Through field trials, my research has demonstrated that trifludimoxazin may be applied prior to soybean planting, at projected field use rates, with minimal risk for crop injury. Additionally, research conducted in field, greenhouse, and laboratory settings shows that trifludimoxazin provides foliar control of giant ragweed (*Ambrosia trifida*) and tall waterhemp (*Amaranthus tuberculatus*), including tall waterhemp biotypes which are resistant to currently-available PPO-inhibiting herbicides. Furthermore, trifludimoxazin can be effectively tank-mixed with other herbicides such as glyphosate, glufosinate, paraquat, or saflufenacil, in order to improve weed control spectrum for burndown applications. Based on these results, trifludimoxazin appears to be an excellent candidate for commercialization, and may provide soybean producers with a novel herbicide active ingredient for use prior to soybean planting, if brought to market.

Advanced Image Analysis for Weed Species Segmentation in Cotton. Bishwa B. Sapkota*, Muthukumar V. Bagavathiannan; Texas A&M university, College Station, TX (269)

Site-specific treatment of weeds has been gaining importance in recent years due to economic savings and minimal impact on the environment. Detailed information regarding spatial distribution of weeds and species composition can greatly facilitate site-specific application of herbicides. The next generation technologies such as unmanned aerial systems (UAS) and deep neural networks (DNN)-based machine learning models have demonstrated the ability to produce such maps. In this study, a DNN-based algorithm was used to segment and classify weeds in cotton in UAS-borne digital imageries. The UAS platform DJI phantom 4 pro was used to acquire RGB imageries over a young cotton, infested with Palmer amaranth, morningglories, Texas millet, and devil's claw. In order to overcome data insufficiency for the deep learning model, 2000 synthetic images of co-mixture of cotton and weeds (1024 × 1024 pixels) diversified through shape, size, and color transformation of real images were produced. Mask-RCNN architecture was used to train on the synthetic dataset by importing the neuron weights from pre-trained image net model in a transfer learning mode. Preliminary results showed that the DNN model developed here has tremendous potential in accurately segmenting and classifying weeds in cotton during early growth stage and indicates that synthetic image driven models could be as effective as those developed with original images.

Cotton (*Gossypium hirsutum*) Defoliation as Affected by Carrier Volume and Droplet Size.
Jacob P. McNeal*[1], Darrin M. Dodds[1], Greg R. Kruger[2], John J. Williams[1], Bradley J. Norris[1], Steven D. Hall[3], William J. Rutland[3]; [1]Mississippi State University, Mississippi State, MS, [2]University of Nebraska-Lincoln, North Platte, NE, [3]Mississippi State University, Starkville, MS (270)

In 2018 and 2019, a field experiment was conducted to evaluate the effect of carrier volume and spray droplet size on the efficacy of cotton (*Gossypium hirsutum*) defoliation programs. This experiment was conducted at the R.R. Foil Plant Science and Research Center in Starkville, Mississippi and at the Black Belt Branch and Experiment Station in Brooksville, Mississippi. Eight-row (7.7m x 12.1m) plots were planted to DP 1646 B2XF. Initial harvest aid applications were made at 60% open boll, and secondary applications to select plots occurred 12 days later. Applications were made with a Capstan® Pinpoint Pulse-Width Modulation (PWM) sprayer on a high-clearance Bowman Mudmaster at a speed of 14.5 km hour^{-1}. This experiment utilized two carrier volumes: 47 and 187 L ha^{-1}, and three droplet sizes: 200 µm, 500 µm, and 800 µm. Defoliation materials included: thidiazuron (TakeDown® SC) applied at 0.15 kg ha^{-1}, ethephon (BollBuster®) applied at 1.5 kg ha^{-1}, tribufos (Folex® 6EC) applied at 0.37 kg ha^{-1}, and pyraflufen-ethyl (ET®) applied at 0.105 kg ha^{-1}. Defoliation programs included: [1A] thidiazuron + ethephon and [1B] thidiazuron + ethephon + tribufos, [2A] 1A + pyraflufen-ethyl + ethephon, and [2B] 1B + pyraflufen-ethyl + ethephon. Visual ratings were taken at 3, 7, and 10 days after application (DAT) for both A and B applications, and included open bolls, green leaves, defoliation, desiccation, and terminal regrowth and basal regrowth. All ratings were normalized to the non-treated control. The center two rows were mechanically using a spindle picker modified for plot research., and seed cotton samples for each plot (4.5 kg) were sent to the University of Tennessee in Jackson, TN for ginning. Fiber quality was determined by the USA classing office in Memphis, TN. The experimental design was a factorial arrangement of treatments within a randomized complete block and included four replications, each with a non-treated control. Data were analyzed in SAS v. 9.4 using PROC MIXED. Means were separated using Fisher's Protected LSD at an alpha level of 0.05. Results did not vary across year or location, and were therefore pooled across these factors. Green leaves 10 days after application A (DAA) varied due to a program*carrier volume*droplet size interaction ($p = 0.0142$). Thidiazuron + ethephon applied at 187 L ha^{-1} with 800µm spray droplets left 23% green leaves on the plant, with all other treatments leaving = 12%. Defoliation 10 DAA varied due to carrier volume ($p = 0.0077$) and a program*spray droplet size interaction ($p = 0.0056$). A carrier volume of 47 L ha^{-1} resulted in 5% more defoliation than 187 L ha^{-1}. Furthermore when pooled across carrier volume, applications of thidiazuron + ethephon with 800µm spray resulted in only 80% defoliation, with all other treatments > 90%. Green leaves 7 days after application B (DAB) a carrier volume*droplet size interaction ($p = 0.0181$). A carrier volume of 47 L ha^{-1} and 800 µm droplets left 19% green leaves on the plant. Conversely, applications of either carrier volume and 200 µm droplets left = 9 % green leaves. Defoliation 7 days after application B (DAB) varied due to program ($p = 0.0236$), carrier volume ($p = 0.0130$), spray droplet size ($p < 0.0001$), and a carrier volume*droplet size interaction ($p = 0.0181$). Initial defoliation applications that did not contain tribufos resulted in 3% more defoliation than those that did. A carrier volume of 187 L ha^{-1} resulted in 2.5% more defoliation than 47 L ha^{-1}, and spray droplet sizes of 200 µm resulted in 2.5% more defoliation than 500 µm, and 7.5% more than 800 µm. In this study, we observed no impact on open bolls, regrowth, fiber quality, or seedcotton yield. As such, our conclusions reflect the impact of defoliation efficacy only. Therefore, these data indicate that lower carrier volumes have a utility in cotton defoliation programs. We hypothesize this is due to the increased concentration of active ingredient within each spray droplet. Secondary applications, if necessary, will benefit from higher carrier volumes and fine spray droplets due to increased coverage of the remaining plant material.

Effect of Herbicide Program, Spray Droplet Size, and Drift Reduction Agent on Glufosinate Efficacy. John J. Williams*[1], Darrin M. Dodds[1], Jacob P. McNeal[1], Steven D. Hall[2], Bradley J. Norris[1], William J. Rutland[2]; [1]Mississippi State University, Mississippi State, MS, [2]Mississippi State University, Starkville, MS (271)

Increasing interest has been placed on managing spray droplet size of herbicide applications to mitigate off-target movement. Drift reduction agents (DRA) have been recommended to reduce driftable fines in the spray pattern. A study was conducted in 2019 near Dundee, MS to evaluate Palmer amaranth (*Amaranthus palmeri*) control with glufosinate and with and without a DRA. The study was conducted using 2 x 2 x 6 factorial arrangement of treatments in a randomized complete block design with four replications. Deltapine 1646 B2XF was seeded at 111,000 seed ha^{-1} on June 20. Factors included: A) PRE of fluometuron at 1.1 kg ai ha^{-1} and no PRE; B) six spray droplet sizes of 150-900 microns in increments of 150 microns; and C) Intact™ at 0.5% v v^{-1} and no Intact™. All treatments received glufosinate at 0.59 kg ai ha^{-1} when Palmer amaranth reached 10-15 cm in height. Herbicide applications were made with a pulse width modulated sprayer using Wilger™ flan fan, non-venturi tips at a speed of 14.5 km hr^{-1} and carrier volume of 140 L ha^{-1}. Data were subjected to analysis of variance using the PROC GLM procedure in SAS v 9.4. Means were separated using Fisher's Protected LSD at a = 0.05. Driftable fines were reduced by 23% when Intact™ was added to the tank mix and as volume median diameter of droplet size increased, driftable fines decreased. There was a negative linear trend in Palmer amaranth control at 7 and 14

DAA ($p < 0.01$). Smaller droplet sizes provided the greatest Palmer amaranth control. Palmer amaranth density was also greatest where larger droplet sizes reduced herbicide efficacy. In conclusion, although the fine droplet size (150 micron) provided the greatest control of Palmer amaranth, a medium droplet size (300 microns) will reduce drift potential without sacrificing herbicide efficacy.

The Genetic Diversity of *Amaranthus tuberculatus*: A Success Story in the American Midwest. Brent P. Murphy*, Patrick Tranel; University of Illinois, Urbana, IL (272)

Waterhemp (*Amaranthus tuberculatus*) is a driver weed species within its native range of the Midwestern United States. The two major subpopulations, var *rudis* and var *tuberculatus*, are largely to the west and east of the Mississippi river, respectively. Admixture between these two subpopulations is well documented throughout the Midwest United States and Southern Canada. This admixture, or the genetic diversity therein derived, may contribute to the success of the species as an agricultural weed. Molecular phylogenies have identified a second amaranth closely related to waterhemp: Sandhills Amaranth (*Amaranthus arenicola*). Native to the central and southwestern great plains, the species is largely considered non-weedy, though it has been observed in agricultural fields. Hybridization experiments between these two species suggest they are within the same primary genepool. The implication of a potentially third waterhemp subspecies are explored.

Chromatography: The Key to Quantifying Herbicide Dissipation. Kayla M. Eason*, Timothy L. Grey, A Stanley Culpepper; University of Georgia, Tifton, GA (273)

Chromatography was named for the colorful bands of leaf pigment that separated after being passed through a column with gravity supplied solvent. Now, chromatography includes the combination of high pressure, various solvents, and a wide spectrum of column types. High performance liquid chromatography (HPLC) is now one of the most powerful tools in analytical chemistry, having the ability to separate, identify, and quantitate various compounds present in a wide range of sample types. While HPLC analysis is mainly used in chemistry, it can also be used to quantitate the persistence of herbicides. In Georgia, pecan growers apply indaziflam for residual weed control. Understanding indaziflam dissipation in pecan groves with varying soil types can help growers make crucial replanting decisions. Vegetable production is also common in South Georgia. Vegetable producers apply herbicides over-the-top of polyethylene mulch beds to mitigate weed pressure before rotating crops. Understanding the dissipation of herbicides from the surface of mulch impacts what herbicides growers utilize. Chromatography can be used to quantify herbicide dissipation in both cropping system situations.Therefore, HPLC analysis was used to quantify indaziflam soil dissipation in pecan from 2016 to 2018. Indaziflam was still present in the soil nearly 600 days after application. In 2019, glyphosate, glufosinate, halosulfuron-methyl, and paraquat dissipation from the surface of plastic mulch was also analyzed using chromatography. Herbicides were all detected at efficacious levels until 18 days after treatment. This data indicates that Georgia producers may be able to use these herbicides over-the-top of mulch beds between crops. In both cropping systems and herbicide application scenarios, chromatography was the key to answering the question of herbicide persistence and dissipation.

Making a Better Glufosinate: Alleviating Environmental Parameters and Improving Efficacy. Grant L. Priess*, Jason K. Norsworthy; University of Arkansas, Fayetteville, AR (274)

Making a Better Glufosinate: Improving Efficacy and Alleviating Environmental VariabilityGL Priess, JK NorsworthyGlufosinate efficacy is variable due to changes in light intensity, humidity, droplet size, and weed size. To improve the consistency of glufosinate, alleviating one or multiple of these application parameters will likewise improve efficacy and provide a more sustainable herbicide. Glufosinate metabolism has been documented in more than 20 weed species. When analyzing the molecular structure of glufosinate, and the common glufosinate metabolites produced by weeds, it can be hypothesized that plant detoxification of glufosinate may be accomplished by glutathione s-transferase enzyme(s). Therefore, a field experiment was conducted in Fayetteville, AR, in 2019, to assess the efficacy of glufosinate in addition with a broad-spectrum glutathione s-transferase inhibitor (4-chloro-7-nitro benzofurazan (NBD-CL) in low-light conditions. Glufosinate was applied alone and in combination with NBD-Cl to 100cm tall Palmer amaranth at 10pm. The addition of NBD-CL to glufosinate resulted in 100% control of 100cm tall Palmer amaranth when applied at 10pm. The addition of NBD-Cl to glufosinate increased glufosinate efficacy by 26% and 40%, when compared to glufosinate alone at 10 am and 10 pm, respectively. The addition of a metabolic inhibitor to glufosinate increased the efficacy of the herbicide when applied in low-light conditions. Reduction in the light dependency of glufosinate can be attributed to the increase in stability of the herbicide molecule in the plant for a lengthened period. The addition of a metabolic inhibitor to glufosinate may improve the utility, decrease application parameters, and ultimately increase the sustainability if increased metabolism via glutathione s-transferase is the primary mechanism for resistance development.

Spray Away the Herbicide Antagonism. Justin S. Calhoun*[1], J Connor Ferguson[2], Luke H. Merritt[2], Kayla L. Broster[2], Zachary R. Treadway[2], Michael T. Wesley Jr.[2]; [1]Mississippi State University, Starkville, MS, [2]Mississippi State University, Mississippi State, MS (275)

Dicamba and 2,4-D traits have been added to soybean and cotton, allowing for over the top applications of these herbicides. Methods to avoid antagonism of glyphosate and clethodim by dicamba or 2,4-D should be utilized to achieve optimum weed control. This study was conducted at the Black Belt Experiment Station (Black Belt) and at the R.R. Foil Plant Science Research Center (R.R. Foil) in fallow fields with browntop millet (*Urochloa ramosa*), broadleaf signalgrass (*Urochloa platyphylla*) and Italian ryegrass (*Lolium perenne* ssp. *multiflorum*) pressure. A tractor mounted dual boom sprayer was modified to spray three application methods: two herbicides tanked mixed, two herbicides in separate tanks mixed in the boom line, and two herbicides in separate tanks applied through separate booms simultaneously. Two salt formulations of dicamba and two salt formulations of 2,4-D were applied with glyphosate through the three application methods to determine difference in herbicide efficacy based on salt formulation and application method. Rates for the first trial at R.R. Foil were applied at 281 and 533 g ae ha^{-1} for dicamba and 2,4-D, respectively. Rates of dicamba, and 2,4-D increased to 562 and 1065 g ae ha^{-1}, respectively in the next two trials at Black Belt and R.R. Foil. Glyphosate was applied at 434 g ae ha^{-1} and clethodim was applied at 68 g ai ha^{-1} with NIS at a rate of 0.25% v/v in all trials. Applying glyphosate with dicamba or 2,4-D resulted in the highest control when applied through separate booms. Antagonism of glyphosate and clethodim was reduced by using the separate boom application method. Antagonism of glyphosate and clethodim from dicamba and 2,4-D was observed through the tank mix and mix-in-line application method.

Ecological Management of Kochia in Irrigated Western Cropping Systems. Ramawatar Yadav*[1], Prashant Jha[1], Andrew R. Kniss[2], Nevin Lawrence[3], Gustavo Sbatella[2]; [1]Iowa State University, Ames, IA, [2]University of Wyoming, Laramie, WY, [3]University of Nebraska-Lincoln, Scottsbluff, NE (276)

Development of glyphosate and ALS-resistant kochia [*Bassia scoparia* (L.) A. J. Scott] in the US Great Plains is a serious concern for producers, especially in sugar beet-based crop rotations due to a lack of alternative chemistries to control kochia in sugar beet. Therefore, there is an urgent need to implement ecological weed management strategies. This requires improved understanding of regional differences in kochia germination patterns (Objective 1) and using that information to design ecological strategies to deplete kochia seed banks (Objective 2). To fulfill objective 1, experiments (two runs) were conducted in 2018 at the MSU-SARC, Huntley, MT to quantify germination characteristics of 44 kochia accessions collected from northern (Huntley, MT; Powell, WY) and southern (Lingle, WY; Scottsbluff, NE) regions. Results indicated that moisture requirements for kochia germination did not differ between northern and southern region; however, kochia from northern region germinated early and had higher cumulative germination than kochia from southern region at low temperatures (4 to 12 C). To accomplish objective 2, field experiments were conducted in 2017-2018 and repeated in 2018-2019 at four sites in MT, WY, and NE to quantify the effect of cover crop (winter wheat), irrigation frequency, and tillage timing on the emergence pattern of kochia, with an ultimate goal to exhaust the kochia seed bank. Cover crop, irrigation, and tillage treatments did not influence kochia emergence at the MT site (northern region). In contrast, irrigation and tillage treatments significantly improved kochia emergence (?33%) from the seed bank at the NE site (southern region). These results indicate that a stale seed bed approach may be more effective in the southern region to stimulate kochia emergence early in the spring with an irrigation and a subsequent tillage to exhaust the seed bank prior to late-planted crops such as dry bean (planted in early June) grown in rotation with sugar beet (planted in mid-April).

Microbial Contributions to Weed Suppression in Conventional and Organic Farm Soils. Liang Cheng*[1], Jenny Kao-Kniffin[1], Antonio DiTommaso[2]; [1]Cornell University, Ithaca, NY, [2]Cornell University, Dryden, NY (277)

Recent advances in sequencing technologies could provide insights into the complex interactions between weed species and soil microbiota that influence weed growth. Specifically, we collected soil samples near common ragweed (*Ambrosia artemisiifolia*) plants in 24 locations with different cropping systems in New York State. We then examined plant-soil feedback effects in a greenhouse experiment. Microbiomes from the 24 farm soils were added to replicated pots containing ragweed seedlings. Mature plants were removed and the soils were re-planted with new seedlings to simulate a plant-soil feedback cycle. Supervised learning methods with a Pearson correlation-based filter were constructed to screen for microbial taxa most linked with weed growth. Distinct microbial fingerprints emerged that separated conventional and organic cropping systems by weed suppression level. A large proportion of the most highly suppressive microbiomes were derived from conventional farms, whereas the microbiomes resulting in positive growth, neutral, or weak suppression of ragweed originated largely from organic farms. The sequencing data revealed that levels of negative plant-soil feedback were influenced by farm management and correlated with microbial diversity of the screened microbiota. Network analysis showed completely different bacterial interaction networks between organic and conventional farms. Our results suggest that the soil microbiota associated with surviving populations of ragweed inhibits the growth of the successive cycle of ragweed plants in conventional farms. Further investigations of these highly suppressive microbiomes using laboratory cultivation techniques and activity-based metagenomics could reveal specific biological agents and natural products that may be suitable for weed management.

The Effect of Common and Novel Pasture Herbicides on Forage Grass Establishment. Wykle C. Greene*, Michael L. Flessner; Virginia Tech, Blacksburg, VA (451)

Abstract not available

WSWS PROJECT 1: WEEDS OF RANGE, FOREST, AND NATURAL AREAS

WSSA SECTION 4: PASTURE, RANGE, FOREST, RIGHTS OF WAY, WILDLAND, AND AQUATIC INVASIVE PLANTS

The Effect of Common and Novel Pasture Herbicides on Forage Grass Establishment. Wykle C. Greene*, Michael L. Flessner; Virginia Tech, Blacksburg, VA (137)

Competition from weeds is one of the greatest factors affecting forage grass establishment. Because of the slow growth of forages from seed, weeds are often able to outcompete forage seedlings, leading to stand reductions or even stand failures. Studies were conducted in Blacksburg in 2018 to determine the effect of new herbicide combinations, florpyrauxifen-benzyl + 2,4-D, and florpyrauxifen-benzyl + aminopyralid, on tall fescue and orchardgrass establishment, compared to other commonly used herbicides. A factorial treatment arrangement was used of herbicide and application timing. Herbicide treatments consisted of 1) florpyrauxifen-benzyl + 2,4-D, (2) aminopyralid + 2,4-D, (3) aminopyralid + florpyrauxifen-benzyl at a low rate, (4) aminopyralid + florpyrauxifen-benzyl at a high rate, (5) metsulfuron, (6) triclopyr + fluroxypyr in addition to a nontreated control. Herbicides were applied at three timings: 1) 2 weeks prior to forage seeding, (2) at seeding, (3) V3 growth stage. A randomized complete block design with four replications was utilized. Visible injury ratings were taken every 30 days for the duration of the growing season. Tall fescue and orchardgrass biomass were taken at the end of the establishment season in May. All data were subject to ANOVA and subsequent means separation was performed using Tukey's HSD (a=0.05). With the exception of metsulfuron, none of the herbicides caused significant injury to tall fescue or orchardgrass, regardless of application timing. Metsulfuron applied 2 weeks prior to seeding initially resulted in 80% and 60% injury to tall fescue and orchardgrass, respectively. However, by the end of the season, there was no injury to tall fescue or orchardgrass from metsulfuron applied prior to, and at seeding. Other than metsulfuron, none of the herbicides applied postemergence caused injury to tall fescue or orchardgrass. Metsulfuron applied postemergence resulted in 30% and 7% injury to tall fescue and orchardgrass, respectively, 30 days after treatment. By 60 days after treatment, injury was 11% and 0% to tall fescue and orchardgrass. There were no differences in orchardgrass biomass between any herbicide treatment. The only herbicide application resulted in a decrease in tall fescue biomass was metsulfuron applied postemergence which caused a 23% reduction in biomass. This research suggests that all herbicides, with the exception of metsulfuron are extremely safe to tall fescue and orchardgrass when applied prior to, at, and after planting.

Scotch Broom (*Cytisus scoparius*) Seed Germination Responses to Light. Timothy B. Harrington*; USDA Forest Service - PNW Research Station, Olympia, WA (377)

Scotch broom, a large leguminous shrub that has invaded forest and agricultural lands in 29 U.S. states, is a copious producer of seeds that remain viable in the soil for decades. Scotch broom's seeds typically germinate following a soil disturbance, such as forest harvesting, but seedling establishment is inhibited when logging debris is retained. Three laboratory studies were conducted to elucidate some of the seed germination responses of Scotch broom to light. The objective of the first study was to determine if light is required for seed germination and whether such a requirement varies with temperature regime. In December 2018 two sets of 50 seeds from each of nine families (i.e., distinct individual plants) were placed in moistened petri dishes that were subjected to a daily dark/light (14/10 h) temperature regime of 10°C/15°C. Petri dishes were wrapped in parafilm to prevent moisture loss. In one set, petri dishes also were wrapped in aluminum foil to eliminate incoming light. After 20 days, cumulative germination (% of seeds) was determined for each petri dish. The experiment was repeated in February and March 2019 for daily dark/light temperature regimes of 15°C/20°C and 20°C/25°C, respectively. Results indicated that Scotch broom cumulative germination did not differ statistically among levels of light (P = 0.40), temperature (P = 0.15), or their interaction (P = 0.22). The objective of the second study was to determine if Scotch broom germination rates differ between red and far-red light environments. Two germinators were outfitted with either red (660 nm wavelength) or far-red LED light bulbs (730 nm wavelength), and each was programmed for a daily dark/light (14/10 h) temperature regime of 15°C/20°C. In October 2017, two sets of 50 seeds from each of 12 families were placed in moistened petri dishes; one set was placed in the red germinator and the other set was placed in the far-red germinator. Over a 20-day period, germinated seeds were counted and removed every 1-2 days. The study was repeated in May 2019 with eight families and in June 2019 with six families. Findings indicated that germination rates were slightly greater under far-red light than under red light during the first five days of each trial. Later in the trials, germination rates were greater in the red germinator. At the end of each trial, cumulative germination under red light averaged 5-7 percentage points greater than under far-red light, although differences were not statistically significant ($P \geq 0.29$). The objective of the third study was to determine if Scotch broom cumulative germination varies with the ratio of red to far-red light. A total of six trials were conducted from July to October 2019 within a germinator outfitted with various combinations of red and far-red LED light bulbs resulting in the following red/far-red ratios: <0.01, 0.4, 0.9, 1.6, 3.6, and 31.1. For each trial, 50 seeds from each of 15 families were placed in moistened petri dishes and subjected to a daily dark/light (14/10 h) temperature regime of 15°C/20°C for 20 days. Germinated seeds were counted and removed every 1-2 days. Results indicated that cumulative germination did not vary significantly among the six ratios of red to far-red light ($P = 0.40$). In summary, this research confirms that: (1) Scotch broom does not have a specific light requirement for seed germination regardless of temperature regime, (2) far-red light causes a brief stimulatory effect on Scotch broom seed germination rates that possibly could confer an advantage for the species' establishment under partially-vegetated canopies, and (3) cumulative seed germination of Scotch broom does not vary significantly among a wide range of red/far-red ratios.

Revitalizing the Use of Crested Wheatgrass (*Agropyron cristatum*) for the Management of Annual Invasive Grasses. Emily B. Repas*, Daniel R. Tekiela; University of Wyoming, Laramie, WY (378)

Many current reclamation efforts of severely disturbed areas depend on rapid revegetation to stabilize and claim the site before it is further degraded or lost to invasion. Because the importance of diverse native communities is well recognized, rapid revegetation is often attempted with native species. Regrettably, the use of native species for rapid revegetation in the Intermountain West is not usually as successful as desired due to the extreme climate, slow growing natives, and lack of commercial seed. When revegetation fails, highly competitive invaders such as downy brome can encroach onto the site and further complicate reclamation efforts, sometimes to the severity where reclamation becomes nearly impossible. An alternative method of reclamation would use dominant, widely available species such as crested wheatgrass to claim and hold a site until physically stable and nearly devoid of invasive propagules. These dominants would then be thinned, and native seeds would be introduced into a more favorable environment that increases the likelihood of successful establishment. This 'assisted succession' is highly dependent on whether crested wheatgrass is easier to manage than an invasion. It is also dependent on the fact that crested wheatgrass does reduce the number of invasive propagules in a reclamation area. This study determined that crested wheatgrass better responded to management methods that utilized tillage. Also, while the percent cover of crested wheatgrass does not influence the number of viable cheatgrass propagules, it does establish an invasion border, and the number of viable propagules decreases with increasing distance from the invasion.

Management Scale Application of Aminopyralid to Sterilize Medusahead (*Taeniatherum caput-medusae*) Seed on Rangeland. Jeremy James*[1], Matthew J. Rinella[2], Josh Davy[3], Larry Forero[4]; [1]University of California Division of Agriculture and Natural Resources, Browns Valley, CA, [2]USDA-ARS, Miles City, MT, [3]University of California Division of Agriculture and Natural Resources, Red Bluff, CA, [4]University of California Division of Agriculture and Natural Resources, Redding, CA (379)

The annual grass medusahead (*Taeniatherum caput-medusae*) is one of the most serious invasive plants on western rangeland. In California, this species establishes and spreads within a matrix of other non-invasive annual forage grasses making management of medusahead extremely difficult. One promising management tool that has recently emerged is the use of growth regulator herbicides such as aminopyralid to manage medusahead. Applying these herbicides at very low rates when medusahead is between the jointing and heading growth stages causes medusahead seeds to develop without an endosperm, rendering them unable to germinate while impacting desired forage species minimally. While small plot studies have shown that these herbicides can cause the current medusahead seed crop to have over 98% sterility, the degree to which use of these herbicides can influence medusahead abundance at a management scale is unknown as medusahead phenology, absorptive leaf area and abundance can vary widely as a result of topography, grazing, site aspect and other site specific conditions. In this study we applied grazing and a low rate of aminopyralid (55 g ae ha^{-1}) in a factorial design to replicated 10-acre plots over two study years to examine how theses integrated treatments could lower medusahead abundance at a management scale. We also conducted companion trials to evaluate how application timing and volume of application influenced medusahead seed sterility. Grazing alone over two grazing seasons did not influence medusahead seed viability or plant abundance. Low rates of aminopyralid in both grazed and non-grazed plots reduced medusahead seed viability an average of 55% which is lower than that reported in the small plot studies. There was substantial variation in the effects of aminopyralid across the 10-acre pasture with some transects showing very low sterility and some transects showing over 90% sterility. This variation appeared to be principally related to variation in phenology among populations due to aspect, grazing and soil depth. Applying aminopyralid 10-days earlier than normal based on average phenology could reduce this variation although the risk to desired species may increase. Alternatively, managers could consider treating different portions of their landscape at different times to account for important small-scale differences in medusahead phenology that influences herbicide effectiveness.

Impact of Relative Early Emergence and Growth Rates of Cool-season Bunchgrasses on Priority Effects with Invasive Grasses. Jaycie N. Arndt*[1], Brian Mealor[2]; [1]University of Wyoming, Arvada, WY, [2]University of Wyoming, Laramie, WY (380)

Priority effects - the impact of early arrival of one species on later arrivals - and differential plant phenological development often distinguish the success of seedling grasses in semiarid rangelands. Invasive annual and cool-season native grasses often emerge early in the growing season, use resources to grow rapidly, and produce seed early. Niche overlap may cause these plant functional groups to compete for temporal resources. We investigated competitive interactions by comparing the effect of early emergence and early growth rates on biomass production in a greenhouse experiment. Native grasses included prairie junegrass (*Koeleria macrantha*), muttongrass (*Poa fendleriana*), squirreltail (*Elymus elymoides*), spike trisetum (*Trisetum spicatum*), and Letterman's needlegrass *(Achnatherum lettermanii*). Invasive grasses included downy brome (*Bromus tectorum*), japanese brome (*Bromus japonicus*), medusahead (*Taeniatherum caput-medusae*), ventenata (*Ventenata dubia*), and bulbous bluegrass (*Poa bulbosa*). One individual of each species was grown alone and each native was grown with each invasive. We measured emergence, daily growth, and final biomass. We used ANOVA to investigate whether competitor identity affected biomass production of each species. Prairie junegrass, downy brome, japanese brome, medusahead, ventenata, and bulbous bluegrass biomass were not decreased by competitors (P= 0.111, 0.142, 0.828, 0.123, 0.29, 0.23, respectively). Biomass of muttongrass, squirreltail, and Letterman's needlegrass were decreased by competitors (P= 0.0051, 0.0081, 0.00053, 0.0329, respectively). We used non-linear regression curves to compare growth of each species for 76 days. Overall, priority effects appear to be species dependent with variation in growth and biomass depending on species-species interactions.

Perennial Pepperweed: Does the Drizzle Method of Herbicide Application Work? Thomas J. Getts*; University of California Cooperative Extension, Susanville, CA (381)

Perennial pepperweed (*Lepidium latifolium*) is a difficult-to-control perennial weed with an extensive root system. In California it is problematic in a wide variety of ecotypes from coastal marshes to riparian areas in the Intermountain Region. Previous research has shown herbicide applications of 2,4-D or chlorsulfuron can be most effective when made at the bud stage of growth. The "drizzle" method is a herbicide application developed in Hawaii by Philip Motooka, which entails herbicide applications at low carrier volumes of 18 L ha^{-1} to 45 L ha^{-1} made with a spray gun, opposed to traditional broadcast applications of higher volumes (e.g 185 L ha^{-1}). An added benefit of this application technique is that more acreage can be covered with a single backpack load. While the "drizzle" method has been tested and shown to be effective for other perennial weed species in California, it was unknown if perennial pepperweed could be controlled using this technique. This research tested the drizzle method of application, alongside broadcast applications of effective products at two locations, one trial in 2017 and another in 2018. The trials were set up with four replications of 3*6 meter plots in a randomized complete block design. At the bud stage of growth, broadcast applications were made using a CO2 pressured backpack sprayer at 185 L per ha^{-1}, and drizzle applications were applied at 28 L ha^{-1} using a handgun. Twelve months after the 2017 trial, only one drizzle application tested (glyphosate 1570 g ae ha^{-1} + 2,4-D 729 g ae ha^{-1}) offered comparable control to a broadcast application of chlorsulfuron 52 g ai ha^{-1}. In the 2018 trial, various drizzle treatments (glyphosate 2241 g ae ha^{-1}, 2,4-D 1463 g ae ha^{-1}, and imazapic 210 g ae. ha^{-1}) all offered comparable control to broadcast applications of chlorsulfuron 52 g ai ha^{-1} twelve months after application. No treatment offered 100% control of perennial pepperweed twelve months after treatment in either year. For managers, this indicates that regardless of chemistry or application method, follow up with control tactics would be required. These trials indicate that the drizzle method could be an option for perennial pepperweed control in certain instances, but more research is needed to confirm under what conditions it is most effective.

Plant Community Data May Improve Susceptibility Modeling for Two Hieracium Species in the Greater Yellowstone Ecosystem. Christie Hubbard Guetling*[1], Lisa C. Jones[1], Don W. Morishita[2], Eva K. Strand[1], Julia L. Piaskowski[1], Timothy S. Prather[1]; [1]University of Idaho, Moscow, ID, [2]University of Idaho, Kimberly, ID (382)

Two invasive species, *Hieracium caespitosum* (meadow hawkweed) and *Hieracium aurantiacum* (orange hawkweed), are recent invaders of the Greater Yellowstone Ecosystem (GYE). Previously, habitat susceptibility models encompassing 1.32 million ha of the GYE were created for these invasive hawkweeds, developed from remotely sensed environmental data and known locations of the invasive plant species. Habitat susceptibility models can be used to prioritize where to conduct ground surveys. These models can be improved through in-field surveys to identify misclassification within the study area. Vegetation types known to be outside potential habitat of a species, but classified as susceptible, should be identified and removed from the model. Perhaps conducting species indicator analysis of foliar cover data would improve classification of susceptibility models and habitat typing of target species. An indicator species is typically associated with specific habitat types and can be used as a surrogate for determining the presence of other, often less common, species. The objectives of this study were: 1) improve habitat susceptibility models by removing dense lodgepole pine stands, 2) identify indicator species of meadow and orange hawkweed then calculate each species' indicator power, 3) determine breadth of plant communities where hawkweeds occur. Cover data were collected along forty-five 20-meter transects within the susceptible range of hawkweeds. During surveys, some areas classified as susceptible by the model proved to be poor habitat for hawkweeds due to dense lodgepole pine tree cover. Dense lodgepole pine stands were digitized and signatures were created to detect the stands and remove them from susceptible classifications in the models. Removing dense lodgepole reduced the susceptible area by approximately 2%, or 13,900 ha, for each model. Assessment of hawkweed plant community composition using Chi-squared analysis and indicator power analysis of indicator species suggest Richardson's geranium and fringed willowherb were strong indicators of both hawkweeds. Another indicator species for orange hawkweed was Canada bluegrass. Additional indicator species for meadow hawkweed include arrowleaf ragwort and ballhead ragwort. These, along with other species present in transects, suggest orange and meadow hawkweed co-occur in several plant habitats: alpine Timothy/sedge, tree fens dominated by forbs, and open lodgepole pine/sedge community types. Meadow hawkweed was found in sagebrush/bluebunch wheatgrass communities while orange hawkweed was absent. This suggests susceptible communities overlap in moist to wet habitats while drier communities are primarily susceptible to meadow hawkweed alone.

Evaluating Native Plant Community Response to Prescribed Burning and Indaziflam. Rachel H. Seedorf*, Shannon Clark, Scott J. Nissen; Colorado State University, Fort Collins, CO (383)

Downy brome (*Bromus tectorum* L.) is known for its ability to accumulate large amounts of litter on the soil surface as plants annually senesce and degrade slowly. Research has shown that about 84% of a soil-applied herbicide can be intercepted by downy brome litter, preventing it from reaching the soil and downy brome seedlings. Prescribed burning is an option used to remove litter to increase the performance of soil-applied herbicides, extend the duration of control, and stimulate native plant communities. No published research has been conducted to determine whether burning increases the efficacy of the newer annual grass herbicide, indaziflam. In August 2017, two downy brome-infested sites were burned. In March and June of 2018, both sites were treated with preemergence and postemergence applications of indaziflam alone, indaziflam + glyphosate, indaziflam + imazapic or rimsulfuron (POST) and imazapic + glyphosate to a burned and non-burned site. Downy brome and native plant species percent canopy cover were collected in July 2019 to determine treatment effects. All herbicide treatments in the non-burned sites reduced downy brome cover to 12.94% ± 3.4, while burned sites were 3.03% ± 2.03. The native plant community responded positively to burning and herbicide treatments. Shannon's Diversity Index was used to measure community diversity, which increased with burning and indaziflam + POST treatments. This indicates that burning can increase the efficacy of herbicides in the first year after application to initiate the process of depleting the soil seed bank and releasing native plant communities.

Invader or Not? Utilizing Drone Remote Sensing to Identify Dalmatian Toadflax (*Linaria dalmatica*) in Rangelands. Chloe M. Mattilio*, Daniel R. Tekiela; University of Wyoming, Laramie, WY (384)

Management of invasive plant populations is most successful when infestations are identified and managed early in the establishment process, but detection of small populations of plants can be difficult. In rangelands of Wyoming, Dalmatian toadflax (*Linaria dalmatica)* is a competitive invasive forb well-adapted to rocky, dry soil, allowing it to colonize steep slopes and rugged terrain. In the Shoshone National Forest near Cody, Wyoming, Dalmatian toadflax populations continue to spread to higher elevations, and scouting and management of populations is being done on horseback. County Weed and Pest authorities need to increase detection success of small populations establishing in the overwintering and nursery slopes of big horn sheep and elk, so Unmanned Aerial Systems (UAS) are being employed for the remote detection of Dalmatian toadflax. Multispectral profiles of Dalmatian toadflax plants were taken through the growing seasons of 2018 and 2019 to build a spectral signature of the plant. Multispectral imagery of a Dalmatian toadflax infested study area was collected with a UAS and precision agriculture sensor, and GPS locations of individual Dalmatian toadflax plants were recorded and used for error estimates of imagery classification, which was performed using a random forest machine learning approach. Spectral signatures of Dalmatian toadflax plants for changes through the growing season, which provides challenges as neighboring species bloom and senesce. Overall, classification results from this study suggest remote detection of Dalmatian toadflax with UAS is possible but must exploit a priori understanding of the phenology of the invaded plant community.

Integrated Management of Leafy Spurge (*Euphorbia esula*) Seed Production in a Riparian Ecosystem. Hannah A. D. Kuhns*, Daniel R. Tekiela; University of Wyoming, Laramie, WY (385)

Leafy spurge (*Euphorbia esula* L.) is an aggressive invasive species in North America that develops persistent infestations and displaces native vegetation. It is difficult to effectively control long-term and in riparian areas, the problem is further exacerbated since the main herbicide that is used to control leafy spurge in upland areas, picloram, is not a viable option near water due to contamination concerns. Leafy spurge has been spreading at a moderate rate throughout the Yampa River Valley, Colorado for decades, with water acting as an additional vector for dispersal. Since an unprecedented flood year in 2011, populations have been more rapidly increasing. Because eradication is impossible for well-established invasions, reducing seed production and the resulting spread to new areas is the most responsible use of management resources in this system. The objective of this project is to reduce leafy spurge seed production in the Yampa River Valley through targeted grazing by sheep, herbicide applications, or some combination of the two. Four sites directly adjacent to the river were established and received an early season grazing event. Late season herbicide treatments of quinclorac, aminopyralid, imazapic, and Rinskor active were applied either on their own or to areas already grazed by sheep. First year data suggest that grazing treatments reduced leafy spurge cover at some sites; however, that reduction allowed potential secondary invaders to establish.

Western Salsify (Tragopogon dubias) and Cutleaf Vipergrass (*Scorzonera laciniata*) Response to Selective Herbicides. Shannon Clark*[1], Rachel H. Seedorf[1], Derek J. Sebastian[2], Scott J. Nissen[1]; [1]Colorado State University, Fort Collins, CO, [2]Bayer, Greeley, CO (386)

Western salsify (*Tragopogon dubius* Scop.) and cutleaf vipergrass (*Scorzonera laciniata* L.*)* are invasive species that pose environmental threats to non-crop areas, roadsides, and other disturbed sites. Western salsify is widespread throughout the US, while cutleaf vipergrass is a newer invasive whose distribution extends out just east and west of the Rocky Mountains. Both are herbaceous plants with yellow flowers, open only a few hours early in the day, and dandelion-like seeds. Research is limited on herbicide options for these two species on rangeland and non-crop sites. Replicated field plots were established from 2018 to 2019 at three locations in Colorado to compare herbicide treatments for Western salsify and cutleaf vipergrass control. At two locations herbicide treatments were applied at two timings, early post-emergent (POST) and late POST, while at the third location herbicide applications were made only at the early POST timing. Visual cover and control evaluations of Western salsify and cutleaf vipergrass along with perennial grass and forb cover were collected at the end of the growing season. Control was significantly improved with the early POST application timing. Treatments containing sulfonylurea herbicides (chlorsulfuron, metsulfuron, nicosulfuron and their combinations) averaged > 95% control while treatments containing auxin herbicides (aminocyclopyrachlor, dicamba, 2,4-D and their combinations) averaged < 50% control at the early POST timing in the year of application. At the site treated in 2018, all SUs continued to provide > 95% control 1 year after treatment. Our data suggest that early POST treatments are critical to achieve control of Western salsify and cutleaf vipergrass. Additionally, sulfonylurea herbicides labelled for rangeland and non-crop sites were identified as a superior option to several commonly used auxin herbicides. Further years of data collection are needed to assess the length of control achieved with these herbicides.

Evaluating the Efficacy of Herbicide to Manage Cheatgrass (*Bromus tectorum*) in High Elevation Sagebrush Steppe. Colter Mumford*, Jane Mangold, John Winnie, Catherine Zabinski, Lisa J. Rew; Montana State University, Bozeman, MT (387)

Cheatgrass (Bromus tectorum) invasion is a widespread non-native plant management challenge in the western United States. Historically, cheatgrass has been less competitive in the northeastern region of the sagebrush biome due to ecological constraints. Anecdotal evidence suggests cheatgrass abundance is increasing on steep south-facing hill slopes in southwestern Montana. This study attempts to quantify the effect of two consecutive fall herbicide (imazapic) applications to control cheatgrass and quantify its potential impact on the native plant community, at 12 sites. Within each herbicide treatment area a tarp was secured to prevent herbicide application to the vegetation. The summer following herbicide application we sampled at two scales: 1) in the area previously tarped (control) and a treated area directly adjacent (10 x10m each); and 2) at a landscape scale, within the herbicide treated area and an adjacent un-treated, un-infested area. For all treatments, plant community richness, diversity, and species cover were sampled using Daubenmire frames (20x50cm).Results show a 99% decrease in cheatgrass abundance following two consecutive years of herbicide application. Furthermore, at the landscape scale, in areas where herbicide was applied, native plant species richness and Shannon's Diversity index (excluding B. tectorum from analysis) was lower compared to un-treated, un-infested areas with similar slope and aspect.

Could Plant - Soil Feedback Play a Role in *Ventenata dubia's* Invasion of the Inland Pacific Northwest? Lisa C. Jones*, Brenda Schroeder, Timothy S. Prather; University of Idaho, Moscow, ID (388)

Paper withdrawn

Impacts of Indaziflam on Biodiversity of Intact Sage-brush Steppe Plant Communities. Jordan Meyer-Morey*, Lisa J. Rew, Jane Mangold; Montana State University, Bozeman, MT (444)

Control of non-native, invasive plants is essential to maintaining and restoring native plant communities, however management efforts can potentially impact existing native vegetation. Indaziflam, a recently developed pre-emergent herbicide, provides residual soil control for up to 3 years and has a unique mode of action, making it a potentially desirable component of weed control programs. Previous studies have shown no negative impacts of indaziflam on native perennial plant community, however most of these studies were conducted in disturbed areas with degraded plant communities. Additionally, impacts of this herbicide to native annual forbs has not been evaluated. Native annual forbs are critical forage for sage-grouse and occupy a disturbance niche that may otherwise be occupied by more disruptive and invasive non-native annual weeds, such as desert alyssum (*Alyssum desertorum*). The objectives of this study were to assess the efficacy of indaziflam on the target weed, desert alyssum, and to evaluate the effects on the native plant community in diverse, intact sage-brush steppe with a focus on native annual forbs. In August 2018, 1m^2plots were established in diverse sagebrush communities of Yellowstone National Park with infestations of desert alyssum. Plots were sprayed with indaziflam at a rate of 6% ai ha^{-1} using an XR 11002 nozzle at 20 psi, in September 2018. One year after treatment percent cover of all plant species in each plot was measured and species richness and Shannon's Diversity were calculated. We found that indaziflam reduced total native species richness and diversity. Importantly, annual forb richness and diversity were also reduced in spray plots. These plots will be continued to be monitored.

Management of Red Bromegrass (*Bromus rubens*) with Indaziflam and Other Pre-Emergent Herbicides. John H. Brock*; Arizona State University, Tempe, AZ (445)

Red bromegrass (*Bromus rubens*) is an alien winter annual introduced to the warm deserts of the southwestern North America. It germinates with autumn and winter rainfall and grows rapidly as temperatures increase in February and March. Peak standing crop occurs in the late spring. When in the vegetative mode, it is consumed by grazing animals, but when it produces seed heads, grazing essentially ceases. Seeds are easily dispersed and have about a three-year life in the seed bank. The problem red bromegrass presents to vegetation managers is it competes with native vegetation, can affect domestic animals with its awns penetrating hair/wool and may cause sores on soft tissues of the mouth. Red bromegrass grass adds to the fine fuel load for wildfires that are harmful to native desert vegetation, especially succulents and species with stem photosynthesis. Management of red bromegrass includes targeted grazing by domestic livestock, prescribed burning, mowing and the use of pre and post emergence herbicides. In the recent years, indaziflam has joined rimusulfuron and imazapic as a pre-emerge herbicide for red bromegrass control.

Indaziflam is very effective (95%) in controlling this problem annual grass and control continues at least 3 years following initial treatment.

Influence of Seeding Depth on Native Species Establishment in the Presence of Indaziflam. Jodie A. Crose*[1], Brian Mealor[2]; [1]University of Wyoming, Sheridan, WY, [2]University of Wyoming, Laramie, WY (446)

Indaziflam is a pre-emergent cellulose biosynthesis inhibitor being evaluated for control of invasive annual grasses in rangelands. Selectivity results from its soil binding properties, and it remains in the top few centimeters of soil, limiting injury to established perennial plants. Impact on seedling recruitment is not well documented. Our objective was to evaluate how emergence is influenced by planting depth with and without indaziflam and whether a trade-off exists between depth and herbicide presence. We evaluated native species tolerance to indaziflam at various seeding depths to understand indaziflam's influence on native species recruitment. We planted seeds in rows at 2.5, 1.3, 0.6, and 0 cm depth in 5.7 L plastic totes containing a 4:1 mixture of clay loam soil and potting medium. We sprayed twelve totes with indaziflam at 73 g ai ha-1 and left twelve untreated. We watered totes four days after application with approximately 1.9 cm per label recommendation. We recorded seedling emergence 21 and 48 days after planting (DAP) and evaluated harvested plant material for biomass, root and shoot length, and distance to first true leaf. Regression analyses indicated that emergence patterns varied by seeding depth and indaziflam for all species 21 DAP. Indaziflam negatively affected emergence from species that require shallower planting depths more than those suited to deeper depths. We observed no treatment effects on plant growth attributes of emerged plants, indicating that upon successful emergence, plants grew normally in herbicide-treated totes. We will investigate these relationships further under field conditions in the future.

Utilizing a Weed Risk Assessment for Listing State Noxious Weeds. Daniel R. Tekiela*; University of Wyoming, Laramie, WY (447)

Limited resources for invasive plant management is a perpetual challenge faced by all land managers. This limitation in resources requires managers to determine what is highest prioritize to manage and what does not reach a high level of priority. For many states, the first layer of prioritization is some form of a noxious weed list that determines what species will be highest priority and where public funding will be utilized. However, the strategies to listing and delisting species on these lists is often unclear and haphazard. In an attempt to standardize the listing of noxious plants in Wyoming and better utilize scientific approaches to determining what is likely to become impactful invasive plants, a weed risk assessment based of the Australian Weed Risk Assessment was developed and implemented for the Wyoming noxious weed list. To date over 100 assessments have been performed on 23 currently or prospectively listed species. Known invasive species elsewhere have been successfully separated from known non-invasive and native plants in Wyoming using this model. Further assessments will be needed, but the model appears to have successfully help in informing what species should be considered for listing on the Wyoming noxious weed list.

Florpyrauxifen-benzyl: A Novel Auxin Herbicide for Aquatic Plant Management. Mirella F. Ortiz*, Franck E. Dayan; Colorado State University, Fort Collins, CO (448)

Hydrilla (*Hydrilla verticillata*; DHV) and Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) are among the most difficult invasive aquatic plants to manage in the United States. They are both widespread and aggressive submersed weed species that often have negative impacts on the aquatic ecosystems and disrupt many human activities. Among the tools available for invasive aquatic plants management, chemical control has become a common and cost-effective method for selective management of invasive aquatic plants. Florpyrauxifen-benzyl was registered in the US for aquatic use in 2018 and is a new reduced-risk synthetic auxin herbicide that has a unique, low-rate, short-exposure, systemic activity for selective control of invasive aquatic plants. Three synthetic auxin mimics are registered for aquatic use (2,4-D, triclopyr and florpyrauxifen-benzyl). 2,4-D and triclopyr are not active on hydrilla when applied at recommended rates, whereas florpyrauxifen-benzyl provides excellent control of this weed. The behavior of florpyrauxifen-benzyl was compared to these other two auxinic herbicides, in terms of absorption, desorption and bioaccumulation (plant concentration factor - PCF). Florpyrauxifen-benzyl absorption by EWM and DHV was 4 and 2.5 times higher than another auxinic herbicide with similar log Kow (2,4-D BEE), respectively. While florpyrauxifen-benzyl had the highest bioaccumulation among the auxinic herbicides, it had the lowest desorption, preserving most of the herbicide in the plant after being moved to clean water.

Management of Ventenata (*Ventenata dubia*) with Indaziflam at Different Preemergent Timings on Conservation Reserve Program Land. Jared A. Beuschlein*[1], Rachel J. Zuger[1], Timothy S. Prather[2], Harold Quicke[3], Ian Burke[1]; [1]Washington State University, Pullman, WA, [2]University of Idaho, Moscow, ID, [3]Bayer, Windsor, CO (449)

Ventenata [*Ventenata dubia (Leers)* Coss.] is a winter annual grass invader in Conservation Reserve Program lands in Eastern Washington and Northern Idaho. Indaziflam has been found to control invasive annual grasses such as ventenata, downy brome *(Bromus tectorum* L*),* and medusahead [*Taeniatherum caput-medusae* (L.) Nevski]. Our objective was to compare indaziflam with and without rimsulfuron at different rates and ventenata timings (2-months PRE, 1-month PRE and early POST) to determine the most effective management strategy for annual grass control. A study with two randomized complete block design trials were conducted in 2018 and 2019. Treatments included indaziflam (73 g ai ha^{-1}, 102 g ai ha^{-1}), indaziflam plus rimsulfuron (35.185 g ai ha^{-}1 + 71.505 g ai ha^{-1} ,53.3 g ai ha^{-1} + 71.505 g ai ha^{-1}, 71.505 g ai ha^{-1} + 71.505 g ai ha^{-1}), and imazapic (123 g ai ha^{-1}). Biomass was quantified 11 and 23 mo after the first treatment timing (MAT) by harvesting aboveground biomass in two 1/10 m^2 quadrats per plot. Application timing did not affect herbicide effectiveness. Indaziflam plus rimsulfuron reduced annual invasive grass biomass by 95% to 20 kg ha^{-1} compared to the nontreated at 510 kg ha^{-1}. Indaziflam controls ventenata, with reductions in biomass still present almost two years after treatment application, regardless of timing of application or rate of indaziflam.

Changes in Botanical Canopy Cover and Seasonal Forage Production with Herbicide Impregnated Dry Fertilizer. Scott Flynn*[1], Byron B. Sleugh[2], D Chad Cummings[3], William L. Hatler[4], David E. Hillger[5]; [1]Corteva Agriscience, Lee's Summit, MO, [2]Corteva Agriscience, Carmel, IN, [3]Corteva Agriscience, Bonham, TX, [4]Corteva Agriscience, Meridian, ID, [5]Corteva Agriscience, Thorntown, IN (450)

Foiliar broadcast herbicide treatments of pastures in the spring can be a difficult task to accomplish, especially when producers depend on custom applicators who are in high demand for other crops. Applications to high value crops or broad acre crops usually take priority during this season but there is also a hesitation to transverse rough pasture terrain and risk equipment damage. To overcome this challenge several range and pasture herbicides are now labelled for dry fertilizer impregnation (DFI) use. The objectives of this study are were to: 1) Compare the level of broadleaf weed control for the newly labelled pasture herbicide DuraCor™ herbicide (Rinskor + Aminopyralid) to GrazonNext® HL (Aminopyralid + 2,4-D, Chaparral™ (Aminopyralid + Metsulfuron), and untreated control (fertilizer only) and; 2) determine the effect of DFI applications on forage dry matter production (kg dm/ha). Study was conducted as randomized complete block design from May 11 to August 22, 2018 on a pasture consisting predominately of Tall Fescue *(Lolium arundinaceum),* Kentucky Bluegrass *(Poa pratensis),* White Clover *(Trifolium repens).* Treatments were: DuraCor at 101 and 126 g ae/ha, GrazonNext HL at 1050 g ae/ha, Chaparral at 143 g ae/ha, and untreated (fertilizer only). Herbicides treatments were impregnated on a 3-way fertilizer blend consisting of nitrogen, phosphorus and potassium, and applied with a Gandy drop spreader at 280 kg/ha. Botanical cover, and herbage mass was determined on 30 to 45-day schedule followed by removal of plot herbage to a height of 10 cm. Broadleaf weed control of DuraCor, Chaparral, and GrazonNext HL DFI treatments provided 75% -95% reduction in broadleaf weed biomass with maximum labeled rates providing numerically greater control. Forage dry matter yield increased at a rate of 1.33 kg dm/ha for each 1 kg dm/ha of broadleaf weeds controlled. Overall DuraCor, GrazonNext HL and Chaparral provided similar broadleaf weed control however, given the suppression effect of metsulfuron-methyl on *Festuca arundinaceum* Chaparral treatments yielded slightly less. ®™Trademarks of Dow AgroSciences, DuPont, or Pioneer and their affiliated companies or respective owners

Growth Regulator Effects on Ventenata (*Ventenata dubia*) Seed Viability Under Field Conditions. Beth Fowers*[1], Brian Mealor[2], William L. Hatler[3]; [1]University of Wyoming, Sheridan, WY, [2]University of Wyoming, Laramie, WY, [3]Corteva Agriscience, Meridian, ID (452)

Invasive annual grasses, such as ventenata, present a challenging natural resource issue in rangelands of the western U.S. While commonly targeted with pre-emergent herbicides, seasonal weather and emergence patterns may make timing of pre-emergent applications difficult. A post-emergent control opportunity may exist where plant sterility is caused by growth regulator herbicides applied at various plant developmental stages. While this approach has been evaluated under greenhouse settings for ventenata, in-field data have not been published. Our objective was to determine the effects of aminopyralid (AMP) and florpyrauxifen-benzyl (FLP) alone, and combined, on viability of ventenata and Japanese brome seed at two post-emergence timings: boot and early bloom. We applied AMP and FLP, alone and combined, at low and high rates in a rangeland site in northeast Wyoming in spring 2019. Effects on seed viability depended on herbicide, rate, timing, and target species. Overall, AMP more effectively reduced seed viability across both species than did FLP alone ($P<0.05$), especially during the boot stage. Higher application rates generally resulted in lower seed viability within an application timing. Viability reduction was more pronounced in Japanese brome than in ventenata. This study supports previous greenhouse research with growth regulator results in a field setting and suggests that post-emergent applications may provide an option for reducing seed viability in problematic annual grasses in early-detection rapid-response situations where a pre-emergent application window was missed.

Impacts of Simulated Trampling on Nonstructural Carbohydrates in Yellow-Flag Iris (*Iris pseudacorus*). Alexandra L. Stoneburner*; Colorado State University, Fort Collins, CO (453)

It has been well documented that the presence of invasive species negatively impacts biodiversity, system interactions, and the local economics of the areas they invade. It is also well understood that one of the most complex challenges associated with invasive species is how best to manage them once they are established. Yellow-Flag Iris (YFI) is a non-native, invasive wetland species that, due to its physiology, has the capacity to exclude native vegetation in riparian areas and form extensive monocutures. While chemical management techniques are often utilized for larger stands, cattle trampling has been shown to be effective as well. Previous work suggests that after multiple years of trampling YFI density and height decrease significantly. It has also been shown that saturated soil conditions amplify these results. While cattle trampling of YFI could be an effective management tool, the question of what is mechanistically driving these responses still remains. One such mechanism could be a reduction in total nonstructural carbohydrates (TNC). To investigate this question, a simulated trampling study was performed. Six treatment groups consisting of both trampled and un-trampled samples, as well as saturated and unsaturated samples, were analyzed. Saturation levels were held constant, and trampling was simulated by applying concentrated pressure to the plant crown. Prior to implementing treatments, as well as again at the conclusion of the study, rhizomes samples were collected from each replicate and a molecular assay performed to determine the chemical moiety. It is our hypothesis that YFI exposed to both trampling and saturated conditions will show the greatest reduction TNCs. Final results are pending, but initial observation supports this theory.

Long-term Outcome of Integrating Herbicide and Seeding in Leafy Spurge (*Euphorbia esula*)-Invaded Rangeland. Matthew J. Rinella[1], Alan D. Knudsen[2], Jim S. Jacobs[3], Jane Mangold*[4]; [1]USDA-ARS, Miles City, MT, [2]Missoula County Weed District, Missoula, MT, [3]NRCS, retired, Bozeman, MT, [4]Montana State University, Bozeman, MT (454)

Integrating herbicides with seeding of desired grasses is sometimes used to reduce weed abundance and increase forage production in invaded rangelands, but insufficient long-term data prevents determining if seeded grasses are likely to become and remain productive enough to justify this expensive practice. We quantified long-term seeding outcomes in a widespread Rocky Mountain foothill habitat invaded by leafy spurge and several exotic grasses. In 2002 three herbicide treatments (none, picloram, imazapic) were integrated with six grass seeding treatments [none, Great Basin wildrye (*Leymus cinereus*), orchardgrass (*Dactylis glomerata*), thickspike wheatgrass (*Elymus lanceolatus*), big bluegrass (*Poa secunda*), bluebunch wheatgrass (*Pseudoroegneria spicata*)]. Biomass of leafy spurge, seeded grasses, and other vegetation was collected 2, 3, and 14 years after treatments were applied. After 14 years, the most productive grass was bluebunch wheatgrass, which produced 900(100, 12000) kg ha^{-1} [mean(95% CI)], about 70% of total plant community biomass. Herbicides increased grasses shortly after application, but they did not benefit seeded grasses after many years. Leafy spurge gradually became less productive in all plots, and seeded and unseeded plots produced similar leafy spurge biomass 14 years after seeding. Although we did not observe a decrease in leafy spurge due to seeding, bluebunch wheatgrass reduced undesired, exotic grasses about 85%. While there is always a risk seeded grasses will remain sparse or fail to establish, our study combined with past studies identifies invaded habitats where seeded grasses have a good possibility of forming persistent, productive stands.

Long-term Downy Brome (*Bromus tectorum*) Seedling Reduction with Indaziflam in Sagebrush-Grassland Plant Communities in Sublette County, WY US. Jake Courkamp*; Colorado State University, Fort Collins, CO (515)

Herbicides have proven an effective tool for reducing threats to ecosystems invaded by downy brome, however it is often difficult to avoid injuring established perennials and long-term control has proven elusive. Indaziflam (Esplanade®, Bayer) has demonstrated the potential to selectively reduce downy brome seedlings and achieve long-term control without harming established plants. We assessed the ability of indaziflam treatment at three different rates (51, 73 and 102g ai/ha), and imazapic treatment (Plateau®, BASF) at the standard rate (123g ai/ha) to selectively manage downy brome at two high-elevation sagebrush-grassland sites near Pinedale, Wyoming. At each site, we measured canopy cover by species and downy brome seedling density in four replicates of small plots that include each treatment and an untreated control. Plant species diversity was also measured in three two-hectare aerial indaziflam treatments (73g ai/ha) and untreated controls of similar size using multi-scale vegetation plots to generate species-accumulation curves. All treatments were applied in September 2016 and the small plots were sampled in June of the following three years, while the multi-scale plots were sampled only in June 2019, three years after treatment (YAT). Comparable reductions in downy brome cover and density between indaziflam and imazapic treated small plots were observed up to two YAT, and in some cases imazapic outperformed indaziflam one YAT. Reductions only remain significant three YAT in indaziflam treated plots. The species-accumulation curves for the multi-scale plots indicate that the rate of native species accumulation does not differ between treated and untreated areas. jacob.courkamp@colostate.edu

Ecosystem Response to Thirteen Operational Indaziflam Cheatgrass (*Bromus tectorum*) Treatments. James Sebastian*[1], Steve Sauer[1], Shannon Clark[2], Derek J. Sebastian[3]; [1]Boulder County Open Space, Longmont, CO, [2]Colorado State University, Fort Collins, CO, [3]Bayer, Greeley, CO (516)

Abstract not available

Evaluating the Efficacy of Various Herbicides for Bulbous Bluegrass (*Poa bulbosa*) Control. Jordan L. Skovgard*[1], Brian Mealor[2]; [1]University of Wyoming, Laramie, WY, [2]University of Wyoming Dept of Plant Sci, Laramie, WY (517)

Bulbous bluegrass is a widespread invasive cool-season perennial grass that reproduces via bulblets. Bulbous bluegrass research is limited and few herbicides are labeled for its management in rangelands. We evaluated efficacy of 11 herbicides, alone and mixed with glyphosate, in controlling bulbous bluegrass at two field sites in northeastern Wyoming. We applied herbicide treatments to 3 x 9-meter plots as a split-plot randomized complete block design with four replicates per site. Glyphosate (520 g ae·ha-1) was applied to 1/3 of each block immediately

following other herbicide applications. We collected post-treatment data 30 and 160 days after treatment (DAT) and 1 year after treatment (YAT). We recorded canopy cover by species in ¼ m^2 quadrats at a density of 6 quadrats per 0.3 are. Additionally, we visually estimated bulbous bluegrass control (%) and damage (%) to perennial grasses and perennial forbs. Data collected 1YAT indicate that all treatments except glyphosate alone decreased bulbous bluegrass cover at one site. Imazapic+Indaziflam, regardless of application rate, effectively controlled bulbous bluegrass, but these two active ingredients were not effective when applied alone. All combination treatments provided greater than 99% bulbous bluegrass control ($P < 0.001$). All treatments containing rimsulfuron and sulfometuron+chlorsulfuron negatively impacted perennial grasses at both sites ($P<0.001$). Sulfometuron+chlorsulfuron applications damaged perennial forbs. Observed species richness varied by glyphosate and residual herbicides ($P<0.001$). Further research will investigate species-specific cover responses, species diversity, and 2 YAT control (%) and damage (%) at both sites.

Restoration of Invasive Annual Grass Degraded Landscapes: Overview of the Indaziflam Field Trial Program. Harold Quicke*[1], John H. Brock[2], Ian Burke[3], Shannon Clark[4], Thomas J. Getts[5], Jane Mangold[6], Brian Mealor[7], Scott J. Nissen[4], Timothy S. Prather[8], Corey V. Ransom[9], Derek J. Sebastian[10], Stephen M. Van Vleet[11]; [1]Bayer, Windsor, CO, [2]Arizona State University, Tempe, AZ, [3]Washington State University, Pullman, WA, [4]Colorado State University, Fort Collins, CO, [5]University of California Cooperative Extension, Susanville, CA, [6]Montana State University, Bozeman, MT, [7]University of Wyoming, Laramie, WY, [8]University of Idaho, Moscow, ID, [9]Utah State University, Logan, UT, [10]Bayer, Greeley, CO, [11]Washington State University, Colfax, WA (518)

Western natural areas and rangeland are undergoing catastrophic degradation through invasion of annual grasses such as downy brome (*Bromus tectorum*), ventenata (*Ventenata dubia*), medusahead (*Taeniatherum caput-medusae*) and red brome (*Bromus rubens*). These grasses compete directly with desirable vegetation for water, nutrients and sunlight. They complete their life cycles from late spring into summer, turning brown and adding fine fuels at the exact time that wildfire risk increases. The result is increased fire frequency and size with impacts that can include societal disruption, health effects from smoke, destruction of infrastructure and degraded habitat for wildlife and livestock. Additionally, the increased fire frequency can prevent desirable perennial grass, forb and shrub species from recolonizing, resulting in invasive grass dominated landscapes. There is an urgent need to slow the spread of invasive annual grasses and to restore degraded areas. Starting in 2015, multiple university researchers installed trials to investigate the use of indaziflam to restore landscapes through control of annual grasses. Trials included the major invasive grass species and covered multiple levels of annual grass infestation. Results showed that a single application of indaziflam herbicide resulted in multiple years of annual grass control, often with rapid biomass increases of desirable perennial species. This provides a new opportunity to start depleting annual invasive grass seedbanks and restore and protect intact desirable habitats. Additionally, indaziflam is a new site of action for annual grass control (Group 29 Cellulose biosynthesis inhibitor) that can mitigate herbicide resistance pressure resulting from current over reliance on Group 2 Acetolactate synthesis inhibitors.

Developing Chemical Control Strategies for the Invasive Weed Oblong Spurge, *Euphorbia oblongata*. Scott Oneto*; University of California Cooperative Extension, Jackson, CA (519)

Oblong spurge is a native of Turkey and Southeast Europe and was introduced into California as an ornamental. It has since escaped and is expanding its range forming dense stands and outcompeting native and desirable plants along riparian areas, roadsides, disturbed areas, grasslands, coastal dunes and oak woodlands. Oblong spurge is an erect perennial to nearly 3 feet high with milky white sap and smooth, oblong leaves. The milky sap of spurges is toxic and can irritate the skin, eyes and digestive tracts of humans and other animals. Cattle tend to avoid foraging spurge, but goats and sheep appear more tolerant to its irritant properties. Flowers consisting of yellow bracts are produced in clusters at branch tips from April – September. Plants reproduce vegetatively from root crowns or via seed that are ejected up to 16 feet when ripe. In summer 2015, an herbicide trial was established in Pioneer, Amador County, California, to test several herbicides at different rates and application techniques. The herbicides and rates tested were glyphosate (Roundup Pro®) at 0.75, 1.5 and 1.2 a.e./acre, imazapyr (Chopper®) at 0.5, 1.0 and 0.8 lbs. a.e./acre, triclopyr ester (Garlon 4 Ultra®) at 2, 4 and 1.6 lbs. a.e./acre, fluroxypyr ester (Vista XRT®) at 0.26 and 0.5 lbs. a.e./acre, aminopyralid / triclopyr (Capstone®) at 0.05/0.5, 0.1/1.0 and 0.04/0.4 lbs. a.e./acre, chlorsulfuron / aminopyralid / triclopyr (Telar XP® / Capstone®) at 0.04 lbs. a.i./acre/0.05/0.5 lbs. a.e./acre, sulfometuron methyl / chlorsulfuron (Landmark®) at 0.06/0.03 and 0.13/0.06 lbs. a.i./acre and aminocyclopyrachlor / chlorsulfuron (Perspective®) at 0.1/0.04 and 0.2/0.08 lbs. a.i./acre. Applications were made using a CO_2 backpack sprayer at 30 PSI and were applied either as a broadcast spray using a ten-foot boom with four 8002XR nozzles at 20 GPA or as a drizzle application using a spray gun fitted with a 0.02” orifice disk at 1.6 GPA. Each plot measured 10 ft. x 20 ft. and each treatment was replicated 4 times in a randomized block design. Results indicate that imazapyr at 0.8 lbs. a.e./acre applied as a drizzle technique provided 100% control one-year after application. Imazapyr applied at 0.5 and 1.0 lbs. a.e./acre using the broadcast method also provided excellent control, 93% and 88% respectively. Triclopyr ester and glyphosate each provided 70% control and showed increased efficacy when treated using the drizzle technique at 1.6 and 1.2 lbs. a.e./acre over the broadcast treatment. Broadcast applications of sulfometuron methyl / chlorsulfuron, aminocyclopyrachlor / chlorsulfuron and aminopyralid / triclopyr provided poor control. These results provide several chemical control options for oblong spurge and give land mangers flexibility with herbicide and application technique in their management programs.

Southern Sandbur (*Cenchrus echinatus*) Control in Bermudagrass Pasture with Indaziflam. Jason Belcher*[1], Tyler Monday[2]; [1]Bayer, Auburn, AL, [2]Auburn University, Auburn, AL (520)

Southern Sandbur (*Cenchrus echinatus*) is a warm-season annual grass that can be difficult to control in bermudagrass pastures. The seeds are produced inside of a specialized bur, which is what presents problems in grazed pastures and hay production. In addition to reducing field production, the burs that are produced also reduce palatability of both forage and hay. In some situations, sandbur can act as a short-lived perennial, which further complicates control. Indaziflam 200SC is a preemergence herbicide labeled for use in several other markets and works by inhibiting cellulose biosynthesis. Research to date has shown that indaziflam could have a fit in range and pasture settings for control of annual grass species. This trial was conducted on the edge of an agricultural field in Alabama with a previous history of sandbur infestation. Treatments compared indaziflam alone at 43.84 and 73.1 g ai ha^{-1}, indaziflam at 43.84 g ai ha^{-1} repeated, and pendamethalin at 2138 g ai ha^{-1} in single and repeated applications. Applications were made in February, June, and August. Applications made during the June and August timings included mestulfuron+ nicosulfuron at 74.8 g ai ha^{-1} and glyphosate at 325 g ai ha^{-1} to control existing plants.Sandbur control from indaziflam at both rates was significantly better than with Prowl from the February timing (70 and 84% vs. 42%, respectively). This was also observed when applications were repeated. Indaziflam at 43.84 ai ha^{-1} applied twice controlled sandbur 91% at 6 MAT. The pendamethalin treatment repeated provided 39% control.The addition of metsulfuron+nicosulfuron and glyphosate improved control for all PRE treatments. Results indicate indaziflam provides good control of southern sandbur when applied in repeated applications.

Collaboratively Addressing the Wilding Invasive Pine Issue Across East Maui - Part 1. Alison C. Cohan*[1], Caleb Wittenmyer[1], Jeffrey Mallinson[2]; [1]The Nature Conservancy of Hawaii, Makawao, HI, [2]Haleakala National Park, Makawao, HI (521)

Pine species have been naturalizing on East Maui for decades primarily via historical pine plantings at Haleakala Ranch and Kula Forest Reserve. A wildfire stimulated an accelerated invasion into the subalpine and alpine zones, causing concern among the three major conservation landowners: Haleakala National Park, The Nature Conservancy (TNC), and the State of Hawaii's Department of Land and Natural Resources. Two prominent species have spread more rapidly than most pines: *Pinus radiata* (Monterey pine) and *Pinus patula* (Mexican weeping pine). They now pose an extreme threat to East Maui's subalpine habitat, which is recovering following the removal of feral hoofed mammals. The need to coordinate and combine the knowledge of fellow conservation landowners arose from this extensive spread into otherwise native-dominant shrublands. We helped form the Maui Pine Working Group in 2014, encompassing several state, non-profit and federal agencies in an effort to leverage our resources and improve best practices for pine control. Maui landowners and stakeholders have tried various chemical and mechanical control methods to control pines for the past 30 years. For many years control focused on ground control using a drill and fill application, controlling 24,634 pines using a 10% Aminopyralid solution. While effective, ground control is time consuming and not feasible for remote outlier trees or those on steep cliffs. In 2014, TNC tested aerial control of pines using a helicopter with a longline attached to its belly and a targeted nozzle that emits low-volume herbicide to control trees that are inaccessible to ground crews. With this aerial application method, TNC flew 9 missions and controlled 2194 pine trees across 800 acres in 4 years, using a mixture of 3% Roundup Custom (Active Ingredient Glyphosate 53.8%), 0.15% Milestone Specialty Herbicide (Aminopyralid 21.1%), 1% MSO Spray Adjuvant (Methylated Seed Oil) in water.

Collaboratively Addressing the Wilding Invasive Pine Issue Across East Maui - Part 2. Alison C. Cohan[1], Jeffrey Mallinson*[2]; [1]The Nature Conservancy of Hawaii, Makawao, HI, [2]Haleakala National Park, Makawao, HI (522)

The montane and subalpine plant communities of Haleakala National Park are among the richest and most ecologically intact in the National Park System. However, the invasion of non-native

Monterey Pine trees (Pinus radiata) is a major threat to this habitat, which is home to many Threatened and Endangered plants and birds. Invasive pine trees have demonstrated an ability to grow quickly and displace Hawaiian rainforest, shrublands, grasslands and sparsely vegetated lava and cinder areas outside the Park. National Park staff, Conservation Partners, and Volunteers have maintained a diligent and active control program primarily using mechanical methods (cutting and pulling) in areas that are accessible on foot, and thousands of pines have been controlled this way in the park. In 2007, the Poli Poli Fire burned over 600 acres of pine-forest on adjacent lands southwest of the park. Released by the heat of the fire, mature pine trees dispersed millions of seeds. Strong Kona (south) winds then spread the seeds across portions of East Maui, including Haleakala crater, where trees began to grow and threaten native habitat on terrain and cliffs that are too steep for staff to safely access.By analyzing satellite images and Gigapan high-resolution panorama photography in 2014, Park staff estimated that approximately 3,000 inaccessible pine trees would need to be controlled in Haleakala Crater from the air. Herbicide trials conducted by The Nature Conservancy and Park Staff indicated the best mixture for aerial spot application was 3% Roundup Custom (Active Ingredient Glyphosate 53.8%), 0.15% Milestone Specialty Herbicide (Aminopyralid 21.1%), 1% MSO Spray Adjuvant (Methylated Seed Oil) in water. In December 2014, the park conducted a pilot aerial pine control project that successfully targeted 185 trees. Working closely with Park Resources Management staff, contracted helicopters applied herbicide to each individual tree using innovative aerial spray equipment developed for invasive species work in Hawaii. Results from the pilot program demonstrated this control method effective. Between 2015 and 2019, Haleakala National Park accomplished 35 helicopter operations, controlling 3,189 pines on the steep slopes inside of Haleakala Crater. Hawaii faces some of the biggest invasive species threats to native ecosystems in the world, but as demonstrated by the success of the pine project, with persistence and dedication, areas of the park can be restored to their natural conditions in order to continue to steward the biocultural resources of Haleakala for future generations.

Automatic Detection of Invasive Weeds in Hawaii Using High Resolution Imagery and Machine Learning. Ryan L. Perroy*[1], Roberto Rodriguez[2], Travis Mandel[1], Pat Perez[1], David Benitez[3], James J. Leary[4]; [1]University of Hawaii at Hilo, Hilo, HI, [2]USDA, Edinberg, TX, [3]National Park Service, Volcano, HI, [4]Department of Agronomy, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL (523)

Through the use of aerial imaging platforms, including Small Unmanned Aerial Systems (sUAS) and helicopters, we can now readily collect cm-scale video and imagery over priority areas of interest, greatly benefiting weed management. But, the need for trained analysts to manually assess the vast amounts of produced imagery creates a bottleneck. This decreases our effectiveness for rapidly detecting targeted plant species over large areas, without similarly large investments of staff time. Here we present results from an automated computer vision (CV) classifier for the detection of *Miconia calvescens* DC and other species of interest, built upon a convolutional neural network using Tensorflow. High resolution imagery datasets, collected from dozens of individual flights at varying altitudes and lighting conditions, were used to train the computer to consistently recognize leaf and canopy characteristics of target plant species. These algorithms were then applied to directories of raw geotagged imagery to identify targets of interest. Real-world coordinates of the identified targets were then estimated from image EXIF and XMP metadata and trigonometric functions. The final output includes a single text file of targets, their estimated confidence values, and geographic coordinates, along with a directory of annotated photos that include the targets of interest. These data can be visualized and used to direct subsequent operations (e.g., intervention, monitoring). Depending on the photo specifications and computer hardware capabilities, computers running these algorithms can process 100s-1000s of images per hour, reducing this bottleneck and freeing analysts and managers to examine and prioritize a much smaller number of curated images.

Herbicide Trials with Brazilian Egeria (*Egeria densa*) for Management in the Sacramento / San Joaquin River Delta. John D. Madsen*; USDA-ARS, Davis, CA (524)

Brazilian egeria (*Egeria densa*) is the dominant submersed plant in the Sacramento / San Joaquin River Delta, displacing native plant species and degrading habitat for endangered fish species. In an effort to identify the best potential herbicides for management of this invasive plant in California, a mesocosm study was conducted at the USDA Aquatic Weed Research Laboratory in Davis, CA. Fifty mesocosm tanks of 160 L capacity were planted with four 3.8L pots of Brazilian egeria and allowed to establish for four weeks before treatment. All pots were harvested from two tanks before treatment for an initial biomass estimate. Four tanks each were treated with bispyrabic sodium (45 ppb), carfentrazone-ethyl (200 ppb), ethylenediamine complex of copper (1000 ppb), diquat (390 ppb), potassium salt of endothall (5000ppb), dimethylalkylamine salt of endothall (5000 ppb), florpyrauxifen-benzyl (50 ppb), flumioxazin (400 ppb), fluridone (60 ppb), imazamox (500 ppb), penoxsulam (60 ppb), and four tanks were conserved as an untreated reference. All exposures were single treatments, static exposures for twelves. Weekly, a visual percent control were estimated for each tank. At the end of twelve weeks, all pots were harvested, and the shoots were dried at 70C for 48 hours. All herbicides produced some statistically significant reduction in biomass. Copper, diquat, endothall dimethylalkylamine and fluridone produced 90% or better control. Carfentrazone (69%) and the potassium salt of endothall (62%) provided better than 50% control, with other herbicides producing somewhat less than 50% control. Field demonstration has substantiated some of these findings. A study of three treatment plots in 2016 found an 85% reduction in biomass in fluridone-treated plots, compared to a 26% increase in biomass in untreated plots. Further field demonstrations are anticipated using diquat. Copper-based herbicides and endothall dimethylalkylamine are not permitted for use in the Sacramento / San Joaquin River system, due to endangered fish species concerns.

Use of Machine Learning to Automate Aquatic Plant Identification from Sensing Technologies. Robert J. Richardson*[1], Maharshi Patel[1], Andrew Howell[2], Shaphan Jernigan[1], Scott Ferguson[1], Greg Buckner[1]; [1]North Carolina State University, Raleigh, NC, [2]North Carolina State University, Sanford, NC (525)

Resource managers commonly utilize hydroacoustic technology during water body surveys for vegetation detection and quantification. Recent developments in data processing have allowed for rapid transformation of raw hydroacoustic data into heat maps for visualization of vegetation density. While this has greatly improved the ability of managers to track density of submersed vegetation, species identification must still be obtained by time consuming point intercept methods. Therefore, the objective of this project was to evaluate machine learning technologies for automated weed identification from hydroacoustic imaging. Geotagged hydroacoustic imagery of three aquatic plant species (*Hydrilla verticillata*, *Cabomba caroliniana,* and *Ceratophyllum demersum*) was collected and used to create a software pipeline for subsurface aquatic weed classification and distribution mapping. Employing deep learning, the novel software achieved a classification accuracy of 99.06% after training.

Economics and Efficacy of Japanese Stiltgrass (*Microstegium vimineum*) Control After Nine Years of Treatments in a Forest Understory. John Brewer*[1], Becky Fletcher[1], Daniel R. Tekiela[2], Angela R. Post[3], Gourav Sharma[1], Vasiliy Lakoba[1], Jacob Barney[1], Shawn Askew[1]; [1]Virginia Tech, Blacksburg, VA, [2]University of Wyoming, Laramie, WY, [3]North Carolina State University, Raleigh, NC (526)

Japanese stiltgrass (*Microstegium vimineum*) is a summer annual, grassy weed that was introduced into the United States around 1919. It is a problematic invasive that has spread from New York to Florida and even as far west as Texas. Due to its detrimental effects on forest ecosystems and biodiversity, many agencies across the U.S. regard Japanese stiltgrass as one of the worst invaders. There are effective chemical and nonchemical programs available for stiltgrass control, but the persistence of its seed in the soil seedbank for three to five years make single year treatments ineffective long-term. At this time, no long-term research has been published that has determined the total time or cost to eradicate Japanese stiltgrass from an area. At Virginia Tech, we have an ongoing nine-year study assessing different chemical and nonchemical management programs for long-term removal of Japanese stiltgrass and the overall economic cost of each including labor, fuel, and chemical. This long-term study was established in the summer of 2011 in Newport, VA. The study was set up as a split-block design with four blocked replications. The chemical treatments were applied using a pump-up backpack sprayer that was calibrated to deliver 140 L/ha. The treatments included pendimethalin at 2.24 kg ai/ha, high-rate glyphosate at 1.68 kg ai/ha, low-rate glyphosate at 0.11 kg ai/ha, sethoxydim at 0.772 kg ai/ha, mechanical removal by weed eater, and an untreated check. The split block design was utilized to allow each treatment two different application programs. The upper section of each treatment required two applications before flowering while the lower section was only treated with a single application. Pre-application and post-application Japanese stiltgrass populations were assessed via point intercept transects (2 transects = 200 points per plot). Also, two soil samples were taken at random from both the upper and lower sections of a plot at the end of each year to evaluate the soil seedbank over time. For economic assessment, there were three main data types collected, which included the amount of time per application per plot, milliliters of product used per plot, and milliliters of gasoline used during each mechanical removal plot. These data will be combined to calculate an overall price per year per management program. From 2011 to 2019, we have observed an approximate 80% or greater decrease in Japanese stiltgrass population in the field from all chemical treatments with a two-application program and 60 to 70% decrease in population when mechanical removal occurs twice. We tend to see less consistency in Japanese stiltgrass reduction from year to year from our single-application programs. Similar trends can be observed from the seedbank data as well. In 2017, all chemical programs, except for the single application of low-rate glyphosate, reduced the Japanese stiltgrass seedbank populations by approximately 70% or greater. Only the two-application program for mechanical removal reduced the seedbank population significantly lower than the untreated check and similar to the chemical programs. We can observe from this data that the two-application program may have some advantage over single applications for some treatments. Even though we have significantly reduced the Japanese stiltgrass population after nine years of treatment, these data show that we have not yet achieved eradication from any treatment program, which could be due to reintroduction from outside sources via animals or environmental factors.

Effect of Spatial Extent on the Performance of Six Forest Invasive Plant Habitat Suitability Models in Wisconsin. Niels A. Jorgensen, Mark J. Renz*; University of Wisconsin-Madison, Madison, WI (527)

Early detection and rapid response of new infestations is recommended as the best approach to prevent establishment and minimize impacts of invasive species. While information about suitable habitat that should be monitored are available at a larger extent (nationwide, statewide), concern exists that these are not accurate on localized scales. To address this problem, we developed ensemble habitat suitability models using five different algorithms for six invasive plant species in Wisconsin at a statewide and watershed scale and tested performance. The state models were built using all data available for the extent of Wisconsin, while the watershed models were developed using only the data within the watershed boundaries. To test whether models correctly predicted new occurrences we performed invasive species surveys on 12 private woodland properties in the Kickapoo Valley Watershed in Southwestern Wisconsin where we documented presence and absence of these target invasive plants. Within this watershed 2,889 data points were collected for the six species during these surveys and were used to field validate the six ensemble models. Models at each spatial scale performed well (AUC > 0.78, TSS > 0.35). When averaged among species, models correctly classified invasive occurrences (true positives, specificity) 70 and 81% from watershed and statewide extent respectively. In contrast, detection of absences (false negatives, sensitivity) was correctly classified 39 and 22% from watershed and statewide extent respectively. While averaged results suggest that a tradeoff exists with respect to spatial extent validation varied among species and scales, with ensembles for two species having specificity values < 80% at the watershed and statewide scale. Results highlight that field validation of any of these models should be conducted to ensure accurate classification. If it is desired to maximize the classification of where invasive species are, models should be developed/utilized from a large area. However, this approach generalizes the models and reduces their ability to predict areas that do not need to be surveyed as habitat is suitable. Stakeholders should consider this limitation when monitoring.

MezaVue Herbicide: Pricklypear Control and Beyond. D Chad Cummings*[1], Byron B. Sleugh[2], William L. Hatler[3], Scott Flynn[4], Charles Hart[5], James R. Jackson[6]; [1]Corteva Agriscience, Bonham, TX, [2]Corteva Agriscience, Carmel, IN, [3]Corteva Agriscience, Meridian, ID, [4]Corteva Agriscience, Lee's Summit, MO, [5]Dow AgroSciences, Stephenville, TX, [6]Texas A&M AgriLife Extension, Stephenville, TX (573)

MezaVue™ herbicide is a new tool for rangeland managers in the southern US. MezaVue combines three active ingredients to bring unprecedented performance on pricklypear (*Opuntia* spp.). Its superior formulation provides faster pricklypear activity, increased uptake and faster kill than picloram alone, amazing individual plant treatment results and more consistent results in IPT, ground broadcast, and aerial broadcast applications. MezaVue has improved oak tolerance, lower use rate, lower odor, and better value than current industry standards for pricklypear control. In addition to pricklypear control in the southwestern US, MezaVue also controls a wide range of invasive and encroaching woody brush, including old man's beard (*Clematis* spp.), Queen's delight (*Stillingia texana*), broom snakeweed (*Gutierrezia sarothrae*), multiflora rose (*Rosa* spp.), and blackberry (*Rubus* spp.). Foliar individual plant treatment applications (MezaVue 1.0% v/v + MSO 1.0% v/v) control many additional brush species, including but not limited to callery pear (*Pyrus calleryana*), ailanthus (*Ailanthus* spp.), scotch broom (*Cytisus scoparius*) and retama (*Parkinsonia aculeta*). MezaVue herbicide is the new standard in pricklypear control, but also provides excellent control of additional brush species across the southern US, giving land managers a new tool in the battle against encroaching brush.

Rinksor + Aminopyralid (TerraVue): A New Herbicide for Noncrop Land Management. Byron B. Sleugh[1], William L. Hatler*[2], Scott Flynn[3], D Chad Cummings[4]; [1]Corteva AgriScience, Carmel, IN, [2]Corteva Agriscience, Meridian, ID, [3]Corteva Agriscience, Lee's Summit, MO, [4]Corteva Agriscience, Bonham, TX (574)

TerraVue is a new herbicide developed by Corteva Agriscience™, for control of broadleaf weeds, including invasive and noxious weeds, and certain woody plants. TerraVue represents an innovative new tool that is a non-ester, non 2,4-D containing, low odor, low use rate formulation that provides post emergence and preemergence residual control of susceptible broadleaf plants and seedlings and some woody plants. TerraVue is now federally registered with USEPA and registered in many states across the US. It will provide control of all species known to be controlled by Milestone® herbicide plus many additional species and offers flexibly in application (ground, aerial, broadcast, or spot treatment). A key component of TerraVue is Rinskor™ active, a novel new active ingredient never before used rangeland and pastures and is an EPA Reduced Risk Pesticide, as is Milestone. In trials over multiple years across the United States, TerraVue provided excellent control of weeds such as yellow starthistle (*Centaurea solstitialis*), Canada thistle (*Cirsium arvense*), musk thistle (*Carduus nutans*), wild carrot (*Daucus carota),* Purple loosestrife (*Lythrum salicaria*), silverleaf nightshade (*Solanum elaeagnifolium*), squarrose knapweed (*Centaurea squarrosa*), spotted knapweed (*Centaurea maculosa*), poison hemlock (*Conium maculatum*), woolly croton (*Croton capitatus*), annual marshelder (*Iva annua*), common broomweed (*Gutierrezia dracunculoides*), common caraway (*Carum carvi*), and many more. Based on these efficacy data, it is anticipated that TerraVue will be a useful tool in the management of noxious, invasive and other weeds in various sites.

Can I Keep My Clover? Rinskor Active: A New Herbicide Enabling Selective Broadleaf Weed Control in White Clover-Grass Pastures. Byron B. Sleugh*[1], Scott Flynn[2], D Chad Cummings[3], William L. Hatler[4], David E. Hillger[5]; [1]Corteva Agriscience, Carmel, IN, [2]Corteva Agriscience, Lee's Summit, MO, [3]Corteva Agriscience, Bonham, TX, [4]Corteva Agriscience, Meridian, ID, [5]Corteva Agriscience, Thorntown, IN (575)

Forage producers often face difficult weed management decisions before, during and after establishing forage stands, especially grass-legume mixes. Currently, the potential impact on legumes in a grass-legume forage stands is a concern when weed management plans include the use of herbicides. This is the single most cited reason by these producers for not using herbicides regardless of the species or density of the weeds present. The most common questions from producers related to the use of herbicides in grass-legume mixtures is "What product will control weeds and not hurt my clover"? While there are herbicides that show some clover selectivity, they do not meet the farmer's expectation of satisfactory weed control of a diverse population of problem weeds in pastures. Rinskor™ active (Florpyrauxifen-benzyl) is the second member of a unique synthetic auxin chemotype, the arylpicolinates (HRAC group O / WSSA group 4) developed by Corteva Agriscience. Arylpicolinates demonstrate novel, differentiated characteristics in use rate, spectrum, weed symptoms, environmental fate, and molecular interaction compared to other auxin chemotypes. ProClova™ herbicide (Rinskor active + 2,4-D amine) is an innovative product developed to offer an expanded spectrum of broadleaf weed control while preserving white clover in pastures compared to other herbicides or mowing. Trials were established in a Randomized Complete Block Design with 3-4 replications (plot sizes varied by location) between 2014-2019 in the United States and multiple European countries to evaluate the efficacy on weeds, crop response of white clover, and overall forage productivity or changes in botanical composition within treated areas. These studies show that ProClova provided better efficacy and a wider spectrum of control compared to other herbicides or mowing and resulted in increased overall forage productivity and forage utilization. ProClova provided greater than 90% control of many important pasture weeds including musk thistle (*Carduus nutans*), plumeless thistle (*Carduus acanthoides)*, poison hemlock (*Conium maculata*), buttercup (*Ranunculus* spp.), wild carrot (*Daucus carota*), tall and western ironweed (*Vernonia* spp.), narrow leaf plantain (*Plantago lanceolata*), and more. These findings showed that forage-livestock producers can successfully use ProClova in an integrated weed management system that will help meet an important forage management objective – control broadleaf weeds with little or no negative impact on desirable forage plants. ®™Trademarks of Dow AgroSciences, DuPont, or Pioneer and their affiliated companies or respective owners

Rinskor + Aminopyralid (Duracor) - A New Herbicide for Control of Weeds in Rangeland and Pastures. Scott Flynn*[1], Byron B. Sleugh[2], William L. Hatler[3], D Chad Cummings[4], David E. Hillger[5]; [1]Corteva Agriscience, Lee's Summit, MO, [2]Corteva Agriscience, Carmel, IN, [3]Corteva Agriscience, Meridian, ID, [4]Corteva Agriscience, Bonham, TX, [5]Corteva Agriscience, Thorntown, IN (576)

Rinksor™ (Florpyrauxifen-benzyl), a new arylpicolinate herbicide from Corteva Agriscience™, has unique activity on key broadleaf weeds and a highly favorable environmental profile. Several of these key species are complimentary to the spectrum of control of aminopyralid, creating the opportunity for a herbicide in rangeland, pastures, CRP, wildlife management areas, and other sites with a differentiated spectrum while preserving some selectivity on desirable forbs. From this combination Corteva Agriscience has created 2 products: DuraCor™ herbicide, a suspension concentrate for rangeland and pasture; and TerraVue™ herbicide, a water dispersible granule for industrial vegetation management. Replicated research in North America from 2017-2019 shows excellent control of a variety of key broadleaf weeds, including noxious and invasive weeds.®™Trademarks of Dow AgroSciences, DuPont, or Pioneer and their affiliated companies or respective owners

Control of Key Rangeland Noxious and Invasive Weeds with Rinskor + Aminopyralid in the Western U.S. William L. Hatler*[1], Scott Flynn[2], Byron B. Sleugh[3], D Chad Cummings[4], David E. Hillger[5]; [1]Corteva Agriscience, Meridian, ID, [2]Corteva Agriscience, Lee's Summit, MO, [3]Corteva Agriscience, Carmel, IN, [4]Corteva Agriscience, Bonham, TX, [5]Corteva Agriscience, Thorntown, IN (577)

Rinskor™ + Aminopyralid (DuraCor™) is a new herbicide developed by Corteva Agriscience for control of broadleaf weeds and certain woody plants in rangeland, pastures, CRP, wildlife management areas, and other sites. DuraCor represents an innovative new tool that is a non-ester, non 2,4-D containing, low odor, low use rate formulation that provides postemergence and preemergence residual control of susceptible broadleaf plants and seedlings, and some woody plants. It will provide control of all species controlled by GrazonNext® and Milestone® herbicides, plus many additional species, and offers flexibly in application (ground, aerial, broadcast, or spot treatment). A key component of DuraCor is Rinskor active, a novel new active ingredient in non-crop sites, and an EPA Reduced Risk Pesticide. In trials over multiple years across the United States, DuraCor provided excellent control of weeds such as Canada thistle (*Cirsium arvense*), common caraway (*Carum carvi*), curly dock (*Rumex crispus*), buckhorn plantain (*Plantago lanceolata*), common mullein (*Verbascum thapsus*) and many more. Based on these efficacy data, it is anticipated that DuraCor will be a very useful weed management tool in rangeland, pasture, and other sites.

Desirable Forb Tolerance to Applications of Rinskor Containing Herbicides in Rangeland and Pastures. D Chad Cummings*[1], Byron B. Sleugh[2], William L. Hatler[3]; [1]Corteva Agriscience, Bonham, TX, [2]Corteva Agriscience, Carmel, IN, [3]Corteva Agriscience, Meridian, ID (578)

Native desirable forbs are a vital part of natural ecosystems around the world. These forb species are necessary in many plant communities for multiple trophic level obligate species. Forb response to aminopyralid has been investigated in the past. The current studies investigated forb response to TerraVue™ herbicide (Rinskor™ + Aminopyralid), a new land management herbicide labeled for control of annual and perennial broadleaf weeds and enhanced control of certain woody brush species. Studies initiated in 2018 and followed in 2019 indicate that 92% of the forb populations were tolerant to moderately tolerant at 1 YAT, similar in visual cover to the untreated check at many trial sites. Preliminary data demonstrate that key species including golden alexanders (*Zizia* spp.), milkweeds (*Asclepias* spp.), and goldenrods (*Solidago* spp.) remained in the plant community the year following applications of TerraVue herbicide. Current research trials indicated several species likely will be decreased in the plant community following TerraVue herbicide application including: sunflowers (*Helianthus* spp.), Scurfpea (*Psoralea* spp.), and wormwood (*Artemisia* spp.), particularly when applied within the growing season. Based on previously reported efficacy data, TerraVue will be a useful tool in the management of weeds and some enhanced brush control in various use sites. In addition, TerraVue herbicide will have minimal long-term impact on many native forb populations, similar to reported results for Milestone herbicide.

Documenting the Impact of Training Municipalities to Control Invasive Plants on Wisconsin Roads. Mark J. Renz*, Leo Roth, Anne Pearce; University of Wisconsin-Madison, Madison, WI (580)

Invasive species continue to spread throughout Wisconsin, impacting the state's economy, environment, and human health. Roadside rights-of-way (ROW) are a common source of new invasions. While ROW managers desire to control invasive populations and prevent their spread, challenges often limit their ability to act (e.g. money, time, knowledge). While efforts to educate ROW managers have been conducted in the past, they have not resulted in management changes. In 2019, we collaborated with private industry and non-profit partners to conduct five workshops. These workshops aimed at engaging ROW managers and promoting options for overcoming obstacles to invasive plant management. Attendees were trained via classroom and field sessions that included management demonstration plots. Classroom training included facilitated discussions focused on how to overcome perceived management obstacles. This approach resulted in locally-tailored workshops with 233 total attendees who represented 53 municipal and 25 county highway departments, state agencies, tribal governments, and cooperative weed management areas. Pre/post surveys were conducted to assess the workshops. While all topics were positively reviewed, the most useful topics identified were demonstration plots and identification of roadside invasive plants (>90% respondents found these topics useful). On average, we improved attendees' knowledge from 1.3 to 2.4 on a zero (no knowledge) to three (great amount of knowledge) point scale, with the largest increases in how to use herbicides and how to develop a management plan. Follow-up surveys were employed to document ROW managers' intent to change practices. Results found attendees manage > 19,000 road miles, and 93% of attendees intend to change some element of vegetation management on their ROW as a result of attending our workshop. Top practices that attendees intend to change include mapping invasive plants (14,364 road miles influenced), changing herbicide application method/timing (12,334 road miles influenced), and developing an invasive species management plan (12,106 road miles influenced). These workshops' success is likely due to our training approach in conjunction with the participation of academic, private, and non-profit organizations. This method could serve as a model for implementing and documenting successful extension efforts for others.

Evaluating the Effectiveness of Hexazinone on Brunswickgrass in Bahiagrass Seed Production Fields. Clay T. Cooper*[1], Brent A. Sellers[2]; [1]University of Florida Extension, Lecanto, FL, [2]University of Florida, Ona, FL (581)

Brunswickgrass (*Paspalum nicorae* Parodi), sometimes referred to as “Brown seeded paspalum”, is a problematic weed in summer perennial grass pastures in the southeast. In Florida we have seen increasing pressure to control this weed contaminate as it is becoming a major threat to livestock and bahiagrass seed industries. This rhizomatous grass is refused by cattle and seed could potentially restrict sales of contaminated bahiagrass seed lots. Currently, management options are limited; therefore, the objective of this research is to develop a management plan for Brunswickgrass in Bahiagrass seed production fields. Two experiments are currently underway with one being a continuation of a two-year titration study and the other focusing on application timing. Experiments were established within Citrus, Sumter and Pasco counties in 2018 to address Brunswickgrass response to the application of hexazinone at 0.14, 0.28, 0.56, 0.84, and 112 kg ai ha^{-1} . In 2019, an application timing study was established assessing control differences between month and rate. Applications were made monthly starting in May until September at rates of 0.56, 0.84, and 1.12 kg ai ha^{-1}.. In the titration study, hexazinone appears to have significant activity. With an application of 0.56 kg ha^{-1} e 80% Brunswickgrass control was achieved. When the rate was increased to at least 0.84 kg ha^{-1} control increased to at least 94%. During the timing study, percent control increased as application timing was delayed. In May 64% control was achieved across all treatment rates and locations, while percent control increased to 95% in September.

Smutgrass Response to Hexazinone Using Different Application Techniques. Brent A. Sellers*[1], José Luiz Carvalho de Souza Dias[2]; [1]University of Florida, Ona, FL, [2]University of Wisconsin-Madison, Madison, WI (582)

Smutgrass species (*Sporobolus indicus* and *Sporobolus jaquemontii*) have been problematic perennial tussock-forming grass weeds in perennial grass pastures of Florida since the 1950s. Hexazinone is the only selective herbicide that can control these smutgrass species. However, control of these smutgrass species can be challenging with this herbicide due to the interaction of hexazinone and the environment. For example, hexazinone applied prior to less than 6 mm and greater than 76 cm of rainfall often results in limited smutgrass control. As a result, many cultural techniques prior to hexazinone have been explored, but neither mowing, burning, nor roller-chopping smutgrass infested pastures prior to application of this herbicide has been beneficial. Similarly, grazing smutgrass prior to applying hexazinone does not increase control when using this herbicide. Therefore alternate application techniques for applying hexazinone are necessary to potentially increase hexazinone efficacy. Experiments were conducted to test the effectiveness of using a weed wiper as well as using fertilizer as a herbicide carrier for application. Wiping experiments were conducted at four different locations from 2017 through 2018 using various rates of hexazinone as well as glyphosate. Results were variable across locations, and concentrations of hexazinone necessary for adequate control of smutgrass was 35 and 60% v/v for glyphosate and hexazinone, respectively. Experiments were conducted in two different pastures near Ona, FL in 2019 using urea ammonium nitrate (UAN; 32%) as a carrier. A factorial arrangement of treatments included hexazinone at 0.56 and 1.12 kg ha^{-1} and nitrogen at 0 and 56 kg ha^{-1}; a non-treated check (with and without 32% UAN) was included for comparison. Treatments were applied in mid-July using a PTO-driven tractor sprayer calibrated to deliver 280 L ha^{-1}. Each treatment combination was replicated 4 times in a randomized complete block design. In a separate experiment, 0.56 and 1.12 kg ha^{-1} were impregnated on 10-5-10 dry fertilizer and spread onto 6 x 24 m plots using a pendulum fertilizer spreader. Visual estimates of smutgrass control were recorded from each plot at 60 days after treatment (DAT). A line-transect was established within each plot prior to the experiment to determine the number of live plants at the start of the experiment and at 60 DAT. The number of live plants at 60 DAT was converted to a percent by comparing with the initial density within each plot. The main effects of hexazinone and nitrogen as well as the hexazinone x nitrogen interaction were significant for visual estimates of smutgrass control. The interaction of nitrogen with hexazinone was evident only at the low rate of hexazinone, and smutgrass control was 1.4-times greater when nitrogen was used as a carrier. For the main effect of hexazinone, smutgrass control was 1.2-times greater when applied at 1.12 vs. 0.56 kg ha^{-1}. Using nitrogen as a carrier also resulted in smutgrass control being 1.2-times greater than when using water as a carrier for visual estimates of control. Similar to the visual estimates of control, the main effects of hexazinone and nitrogen as well as the interaction of hexazinone and nitrogen were significant for plant counts at 60 DAT. Smutgrass density was 2.2-times greater in plots that were treated with hexazinone at 0.56 kg ha^{-1} when water was used as a carrier compared to the same rate when nitrogen was used as the carrier. There were no differences when hexazinone was applied at 1.12 kg ha^{-1} in water or nitrogen as a carrier. Issues with even spread across the entire experimental plot with the pendulum spreader limits the effectiveness of dry fertilizer impregnation. The results of this research is promising, however, further research should be conducted to evaluate the effect of different rainfall volumes after application of hexazinone with 32% UAN.

WSWS PROJECT 2: WEEDS OF HORTICULTURAL CROPS
WSSA SECTION 2: HORTICULTURAL CROPS

Pyroxasulfone for Faba Bean and Safflower Production. Harlene M. Hatterman-Valenti*, Johnson M. Burton, Auwarter M. Collin, Kutay Yilmaz; North Dakota State University, Fargo, ND (299)

Faba bean (*Vicia faba*) and safflower (*Carthamus tinctorius*) are becoming important components of cereal-dominated cropping systems in North Dakota due to their economic and nutritional values; ability to break graminaceous crop disease cycles, and environmental importance. Unfortunately, the weed control options are rather limited. In 2019, four trials with faba bean (two irrigated, two dryland) and one dryland safflower trial were conducted to evaluate pyroxasulfone preemergence use for weed control and crop safety. In general, season-long control of annual broadleaves and grasses was excellent. Control of common lambsquarters, common purselane, redroot pigweed, and annual grasses (primarily green foxtail) increased slightly with increasing rate of pyroxasulfone for two of the three dryland locations. Common lambsquarters control at the irrigated site near Absaraka increased with increasing pyroxasulfone rates. Crop injury was slightly greater with irrigation, but was less than 10% for all treatments. Faba bean yields were not affected by herbicide treatments at Oakes, where yields were low due to excessive moisture from 177 mm greater than normal rainfall during the growing season. Mean yield across treatments was 1120 and 1147 kg/ha for the dryland and irrigated trials, respectively. Faba bean yields at Absaraka, ND, were also reduced by wet growing conditions where dryland and irrigated trial yields were 1130 and 460 kg/ha, respectively, yet non-significant treatment effects for both trials. Dryland safflower yields at the Prosper location were reduced by prevailing wet growing season conditions associated with 164 mm above normal rainfall during the growing season. Mean safflower treatment yields ranged from 610 to 890 kg/ha and were not significantly different. Overall results suggest that pyroxasulfone could provide growers another weed management tool when producing faba bean or safflower.

Strawberry Tolerance and Flumioxazin Persistence Under Plastic Mulch in Florida Strawberry. Nathan Boyd*[1], Ramdas Kanissery[2]; [1]University of Florida, Balm, FL, [2]University of Florida, Immokalee, FL (300)

In Florida, strawberries are grown on raised, plastic covered beds during the winter months. 214 g ai ha^{-1} of flumioxazin is often applied under the plastic mulch prior to transplant to control broadleaf weeds that emerge in the planting holes. Research trials were conducted in Balm, Florida, in 2017 as well as Balm and Dover, Florida, in 2018 to evaluate multiple rates of flumioxazin for crop tolerance, berry yield and soil persistence. 0, 53.5, 107, 214, 428, 857, 1714, 3427 and 6854 g ai ha^{-1} flumioxazin were applied immediately prior to laying the plastic mulch at GCREC in 2017 and 2018. In 2018, rates up to 857 g ai ha^{-1} were applied at Dover, Florida. Crop damage never exceeded 10% at Dover even at 8X the label rate. Damage ratings at GCREC were higher but damage was not significantly different than the nontreated control at 4X the label rate but 54% foliar damage was observed at 8X the label rate and plants did not recover throughout the season when damage occurred. Berry yields were unaffected by flumioxazin up to 4X the label rate at Dover but at 8X the label rate yields were 20% lower than the nontreated control. At GCREC in 2017 and 2018, berry yields were 40 and 28% lower respectively, where flumioxazin was applied at 4X the label rate but yields were unaffected at lower rates compared to the nontreated control. Flumioxazin residues in the soil under the plastic mulch did not change over the production season. We conclude that flumioxazin is very safe on strawberry at label rates and that the herbicide persists throughout the growing season.

Weed Control in Organic Highbush Blueberries. Marcelo L. Moretti*; Oregon State University, Corvallis, OR (301)

Field studies were conducted in 2018 and 2019 to evaluate the efficacy and performance of organically approved weed control methods. Treatments consisted of saturated steam, brush weeder, ammonium nonanoate (24.3 kg ai ha^{-1}), capric plus caprylic acid (33.2 kg ai ha^{-1}). A nontreated control was included. The studies were organized in randomized complete block with 5 by 5 factorial arrangement. Factor A consisted of the five treatments listed above. Factor B was a second application of one of the five treatments 28 DAT. A total of twenty five treatments were evaluated. Treatments were applied to the base of blueberry plants. The experiment was conducted once in the spring and twice in the summer. A lower efficacy was observed in treatments during the spring study (<30%) compared to the summer (30 to 70% control) because rainfall promoted new weed seed germination. Steam and brush weeder reduced weed biomass to 30% and 50% of the nontreated biomass in the spring, and 43% and 47% in the summer. Ammonium nonanoate reduced weed biomass only in the summer study. The brush weeder and the steam were 3- to 6.5-fold more cost-effective than organic herbicides. These results indicate that saturated steam and brush weeder are effective tools for weed management in organic blueberry.

Screening of Herbicides for Selective Weed Control in Brassicaceous Crops. Ed Peachey*; Oregon State University, Corvallis, OR (302)

Weed control in food and seed crops of the Brassicaceae family is a challenge. Herbicides commonly used in these crops often do not control common weeds such as shepherdspurse or other broadleaf weeds. Cultivation technology is rapidly advancing but plant arrangement within rows does not allow in-row cultivators to operate effectively in many of these seed crops. The objective of this project was to screen under-exploited herbicides for potential use in cruciferous crops. Radish was tolerant to dimethenamid-P at 1.85 to 3.70 kg ha^{-1} applied immediately after transplanting and at the 2-leaf stage when grown for seed. Fluroxypyr controlled hairy nightshade and shepherdspurse in direct-seeded radish grown for seed. Radish growth was reduced by fluroxypyr applied at 0.098 kg ha^{-1} but did not affect seed yield or quality. Broccoli was more tolerant than radish or napa cabbage to sulfentrazone applied POST at 0.105 and 0.210 kg ha^{-1}. Charcoal applied in a 3.8 cm band over the seed row at planting nearly eliminated the injury caused when sulfentrazone was applied post plant surface to broccoli, napa cabbage, radish and other Brassicaceous crops.

Don't be a Wet Blanket - Hit the Bullseye in Potatoes with Targeted Tank Mixes. Pamela J.S. Hutchinson*; University of Idaho, Aberdeen, ID (303)

Some potato growers in the Pacific Northwest (PNW) use the same combination of herbicides across all of their potato fields regardless of weed species present in each field i.e. a “blanket” herbicide program. The weed species in a given field, however, should dictate which herbicides to use. In other words, tank mixtures should be designed to target the weed species in each field. A chart has been created to provide the effectiveness of herbicides labeled for use in potatoes in the PNW and Canada on weed species common to potato production areas. Herbicide mechanism of action (MOA) classification was included in the table for each herbicide. The chart can be used to choose the specific combination of weeds species in a field and then choose the herbicides to include in a tank mixture targeting that combination. The information provided in the chart will also lead to choosing herbicides with different MOA, and if possible, effective on the same species in order to prevent or delay the development of herbicide resistance.

Two Chipping Potato Cultivar Plant Back Responses When Mother Plants Received Sub-lethal Dicamba And/or Glyphosate Rates. Matthew Brooke, Collin M. Auwarter, Harlene M. Hatterman-Valenti*; North Dakota State University, Fargo, ND (304)

Increased use of glyphosate and dicamba tolerant soybean has the potential to move off-target and damage seed potatoes (*Solanum tuberosum*), especially in North Dakota where crop diversity is great. For certified seed potato growers, this would not only affect tuber yields the current season, but potentially the following growing season as well, when the daughter tubers are planted as seed. The objective of this study was to determine the effects of 'Atlantic' and 'Dakota Pearl' tubers, used for seed from mother plants that were exposed to glyphosate at 40 or 197 g ae ha^{-1}, dicamba at 20 or 99 g ae ha^{-1}, or the combination of glyphosate and dicamba the previous year at the tuber initiation stage. At 8 weeks after planting (WAP), 'Atlantic' and 'Dakota Pearl' daughter tuber seed from mother plants receiving glyphosate at 197 g ha^{-1}, or the combination of glyphosate and dicamba, had reduced emergence by 17 and 24% when compared to the non-treated, respectively. Furthermore, at 7 WAP, 'Atlantic' and 'Dakota Pearl' daughter plants from mother plants receiving the combination of dicamba at 99 g ha^{-1} plus glyphosate at 197 g ha^{-1} or glyphosate at 197 g ha^{-1} had reduced plant height by 16 and 20%, compared to the non-treated, respectively, which also reduced canopy coverage. Daughter plants from the mother plants for both cultivars that received the combination of glyphosate at 197 g ha^{-1} and dicamba at 99 g ha^{-1} had a 21% total yield reduction when compared to the non-treated. Results from the two field trials suggest that the combination of glyphosate at 197 g ha^{-1} and dicamba at 99 g ha^{-1}, carried over from mother plants to daughter tubers for both cultivars, the following growing season, to affect total yield from the daughter plant injury. Further research needs to evaluate the influence of environmental stresses on the potato response to sub-lethal amounts of glyphosate and/or dicamba.

Marking of Vegetable Crop Plants to Ensure Recognition by Automated Weeders. HannahJoy Kennedy[1], Steve Fennimore*[1], David Slaughter[2]; [1]University of California, Davis, Salinas, CA, [2]University of California, Davis, Davis, CA (305)

Limited herbicide options and shortages of hand weeding labor threaten vegetable crop producer profitability. Many vegetable crops are dependent on intra-row handweeding to remove weeds left by herbicides and inter-row cultivators. Weed control within the crop rows is necessary to establish the crop and prevent yield loss. Better weed removal technologies are needed to reduce dependence on manual labor for intra-row weed control. Intelligent cultivators have come into commercial use to remove intra-row weeds and these devices can reduce cost of hand weeding. However, intelligent cultivators currently on the market use pattern recognition to detect the crop row and do not differentiate between crops and weeds, thus do not work well in high weed populations. One approach to crop/weed differentiation is to place a machine detectable mark or signal on the crop, i.e., the crop has the mark and the weed does not, facilitating weed/crop differentiation. Lettuce and tomato plants were marked with labels and topical markers, then cultivated with an intelligent cultivator programed to identify the markers. Results from field trials in marked tomato and lettuce found that the intelligent cultivator removed 90% more weeds from tomato and 66% more weeds from lettuce than standard cultivators without reducing yields. Accurate crop and weed differentiation resulted in a 45 to 48% reduction in hand-weeding time per hectare.

Inter-row Cultivation Integrated with Residual Herbicide Programs in Sugarbeet. Nathan H. Haugrud*[1], Thomas J. Peters[2]; [1]North Dakota State University, Fargo, ND, [2]North Dakota State University / University of Minnesota, Fargo, ND (306)

The migration of waterhemp (*Amaranthus tuberculatus*) into northern sugarbeet (*Beta vulgaris*) growing regions has prompted sugarbeet producers to utilize inter-row cultivation in their weed management programs as no currently registered herbicides can control glyphosate-resistant (GR) waterhemp postemergence. Mechanical weed control tools such as inter-row cultivation was common in sugarbeet until the release of GR sugarbeet cultivars in 2008 made the use of inter-row cultivation unnecessary. Today, producers are using inter-row cultivation to remove weeds that glyphosate did not/cannot control, but producers want information on the effectiveness and safety of inter-row cultivation in their residual herbicide programs. Two field experiments were conducted in Minnesota and North Dakota across three years. The first experiment, focusing on weed control, was conducted across four environments to evaluate efficacy of cultivation two weeks following a residual chloroacetamide herbicide program. The second experiment, focusing on crop safety, was conducted across six environments to evaluate the effect of cultivation timing on sugarbeet yield components. Cultivation was performed at 4- to 5-cm deep at 6.4 km h^{-1} approximately two weeks after herbicide application in the efficacy experiment. The safety trial was cultivated with the same methods every two weeks starting June 22 and ending August 17 and treatments were a combination of cultivation dates up to three passes and an untreated control. Results from the efficacy trial demonstrated cultivation significantly improved waterhemp control 11% and 12%, 14 and 28 DAT, respectively. Weed density, however, was dependent on precipitation after cultivation. Cultivation had no effect on waterhemp density in three environments, but one environment near Galchutt, ND in 2019 showed waterhemp per m^2 increase 600% and 200%, 14 and 28 DAT, respectively. Weather data indicated Galchutt, ND in 2019 received 105 mm of precipitation in the 14 days following cultivation, which likely stimulated a new flush of weeds. Results from the safety trial demonstrated root yield and recoverable sucrose ha^{-1} were not affected by cultivation timing or up to three cultivation passes in a season. Sucrose content was reduced 0.4% by cultivating twice in a season regardless of date. Multiple cultivations in-season can destroy leaf tissue which is likely responsible for the reduction in sucrose content. These data across weed control and crop safety experiments indicate cultivation can be a valuable tool to control weeds that herbicide cannot, but excessive precipitation and open crop canopy following a cultivation event can create an environment conducive to further weed flushes.

Better Bunch: Evaluating the Impact of Sweetpotato Growth Habit on Yield and Weed Competition. Matthew A. Cutulle*[1], Phillip Wadl[2]; [1]Clemson University, Charleston, SC, [2]USDA-ARS, Charleston, SC (307)

Tolerance to weed interference is a desirable trait to select for in a sweetpotato breeding program. Most commercial cultivars exhibit a creeping-type growth habit. Cultivars exhibiting a vine-type growth habit are typically susceptible to weed interference. Comparatively, sweetpotato plants that exhibit a bunch-type growth habit are more competitive against weeds. However, there are a limited number of bunch type cultivars on the market. The USDA United State Vegetable laboratory in collaboration with the Clemson vegetable weed science program are currently screening for bunch typed sweetpotato varieties. This presentation will update the progress of the USVL sweetpotato breeding program as it relates to weed interference studies and potential future germplasm releases.

Yellow Nutsedge (*Cyperus esculentus*) Interference in Simulated Sweetpotato (*Ipomoea batatas*) Plant Beds. Stephen L. Meyers*[1], T. Casey Barickman[2], Jeffrey L. Main[3]; [1]Purdue University, West Lafayette, IN, [2]Mississippi State University, Verona, MS, [3]Mississippi State University, Pontotoc, MS (308)

Relatively few studies have been conducted to investigate the impact of weeds on sweetpotato slip production. Greenhouse experiments were conducted in 2016 at Pontotoc and Verona, Mississippi. On March 3 (Pontotoc) and 7 (Verona) landscape fabric was placed in the bottom of polyethylene lugs, each 0.22 m^2, then approximately 5 cm of a 1:1 (v/v) blend of soilless potting media and masonry sand was added. The resultant substrate had an organic matter content of 1.9% and pH 6.2. Beauregard sweetpotato storage roots, each 85 to 227 g and several with emerging sprouts $\leq$1 cm, were placed longitudinally in a single layer on the substrate then covered with an additional 3 cm of substrate. At the same time, but in separate lugs, nutsedge tubers were pre-sprouted. Four days later, after the nutsedge tubers sprouted, they were transplanted equidistantly into sweetpotato-containing lugs at six densities: 0 (weed-free control), 18, 36, 73, 109, and 145 m^{-2}. The experiment design was a randomized complete block with four replications. Trials were terminated 55 and 60 days after planting at Pontotoc and Verona, respectively. Predicted total sweetpotato stem cuttings (slips) decreased linearly from 399 to 312 m^{-2} as yellow nutsedge density increased from 0 to 145 m^{-2}. Predicted total slip dry weight at a yellow nutsedge density of 145 m^{-2} was reduced 21% compared to the weed-free control. Based on a Fisher's protected LSD ($P < 0.05$) analysis of rotten storage roots, yellow nutsedge at a density of 145 m^{-2} resulted in more rotten storage roots (13 m^{-2}) than densities of 0 to 109 m^{-2} (3 to 7 m^{-2}). In response to increasing yellow nutsedge density, sweetpotato seeds roots also exhibited increased proximal end dominance. Given the ability of yellow nutsedge to reduce sweetpotato slip production, additional research is needed to determine suitable control measures.

Trends in Collaboration: Minor Use Foundation, Inc. - Working with Governments, Grower Groups, and Specialty Crop and Minor Use Organizations on Techology Tools. Dirk C. Drost*; Minor Use Foundation, Inc, High Point, NC (309)

The Minor Use Foundation, Inc was incorporated in 2018. The Foundations goals are: 1) Establish a collaborative international approach to address MRL needs for specialty crops and minor uses; 2) implement priorities resulting from the Global Minor Use Priority Setting Meetings; 3) provide funding for qualifying partner organizations to; 4) fund a research program to obtain MRLs for agreed products; and, 5) coordinate activities with organizations that work throughout the world. The foundation delivers these goals by: 1) seeking and obtaining funds from government grants, foundations, non-profits, and industry to support the mission of the Foundation; 2) establishing and implementing an Advisory Council to provide input and advice: and 3) reporting progress and outcomes to partners, stakeholders, and growers and grower organizations. The Minor Use Foundation, Inc is governed by a Board of Directors. The Foundation established a program of work in Southeast Asia in 2019 and implemented work in early 2020 to support grower needs globally.

The Effect of 2,4-D on Hazelnut Abscission. Larissa Larocca De Souza, Marcelo L. Moretti*; Oregon State University, Corvallis, OR (310)

Hazelnut suckers are commonly controlled with 2,4-D amine, but anecdotal reports suggest that the use of 2,4-D in sucker control delays natural abscission in hazelnut. Hazelnuts naturally abscise and are collected from the orchard floor. A delay in abscission may reduce nut quality when abscission coincides with the onset of the rainy season, increasing mold and soil in the nuts. A longer-term field experiment was begun in 2018 to assess the impact of 2,4-D on nut abscission. Treatments, applied in 2018 and 2019, included four applications of 2,4-D at 1.1, 2.2, and 4.4 kg ai ha^{-1}, glufosinate at 1.1 kg ai ha^{-1} and an untreated control. Treatments were directed to the suckers. A simulated drift of 2,4-D at 0.01 and 0.1 kg ai ha^{-1} were applied once per season to the tree canopy. Hazelnut abscission was monitored twice weekly by counting the presence of selected nuts and by harvesting all nuts on the floor. Binomial logistic and non-linear regression analysis was used to estimate the time for 50% nut abscission. The simulated drift of 2,4-D delayed hazelnut abscission. Trees receiving 2,4-D drift were 2 to 11 times more likely not to abscise nuts compared to trees not receiving drift. The time required to abscise 50% of nuts was five days greater in simulated drift with 2,4-D 0.1 kg ai ha^{-1} as compared to the untreated control. Simulated drift reduced yield by up to 36%; nuts were retained in the trees for over 12 months after drift simulation. These data indicated that 2,4-D drift can delay nut abscission, highlighting the importance of drift control measures.

Overlapping S-Metolachlor Treatments for Weed Control in Lima Bean. Kurt M. Vollmer*[1], Mark VanGessel[2], Quintin R. Johnson[2], Barbara A. Scott[2]; [1]University of Maryland, Queenstown, MD, [2]University of Delaware, Georgetown, DE (367)

More processing lima bean acreage is planted in Delaware than any other state. The presence of herbicide-resistant weeds in the area has limited herbicide options for control. Overlapping herbicides is a technique that involves sequential applications of soil-applied residual herbicides in order to overlap the herbicide's activity before the first herbicide dissipates. Separate field and greenhouse studies were conducted to evaluate weed control and lima bean response to *S*-metolachlor applied as an overlapping residual treatment.The greenhouse study evaluated the response of six lima bean varieties to *S*-metolachlor applied to lima bean plants at the first trifoliate stage. Application rates consisted of a 1X (0.8 kg ha^{-1}), 2X, 4X, and 6X rate. The total amount of lima bean injury varied across trials, but the 4X and 6X rates caused greater injury compared to the 1X and 2X rates, which showed almost no injury. The field study evaluated weed control efficacy and lima bean response to *S*-metolachlor applied PRE at 1.1 kg ha^{-1} or 1.3 kg ha^{-1}, followed by a second application of *S*-metolachlor applied early-POST (2 to 3 wk after planting [WAP]), mid-POST (3 to 4 WAP, or late-POST (4 to 5 WAP) at 0.8 kg ha^{-1} or 1.1 kg ha^{-1}. Although crop injury was observed following POST applications, all treatments resulted in less than 8% injury 1 wk following the last post application. *S*-metolachlor treatments resulted in at least a 96% reduction in Palmer amaranth density. However, the effect of POST rate/application timing was not significant. Despite the reduction in Palmer amaranth, *S*-metolachlor treatments did not provide 100% control of all weed species present. Lima bean yields were higher in *S*-metolachlor treated plots, regardless of application rate/timing. Our results show that, overlapping *S*-metolachlor treatments alone do not provide acceptable levels of weed control. However, excellent crop safety was demonstrated when *S*-metolachlor was applied as a broadcast treatment to emerged lima bean. Therefore, this approach could be used to provide additional residual weed control following in-season cultivation.

Investigating the Genetic Basis of Herbicide Tolerance in Snap Bean. Martin Williams*[1], Alvaro Garzon[2], Phillip Miklas[2], James Myers[3], Ed Peachey[3]; [1]USDA-ARS, Urbana, IL, [2]USDA-ARS, Prosser, WA, [3]Oregon State University, Corvallis, OR (368)

Snap bean, the vegetable form of common bean (*Phaseolus vulgaris* L.), is grown for both processing and fresh market in several regions of the U.S. Effective weed management is important for not only protecting crop yield but also minimizing contamination of harvested product with foreign material such as toxic nightshade berries or stems of pigweed plants. The overall aim of the research was to investigate crop tolerance to specific herbicides not currently registered for snap bean. The research objectives were to 1) quantify snap bean response to pyroxasulfone or sulfentrazone, and 2) identify candidate genes responsible for any cultivar tolerance to each herbicide. Using SnAP, a snap bean diversity panel that has been genotyped with ~25,000 single nucleotide polymorphisms (SNPs), we evaluated the response of 277 entries to pyroxasulfone (420 g ai/ha) and sulfentrazone (860 g ai/ha) applied preemergence. Multiple Genome Wide Association

(GWAS) models were used to examine crop stand and plant biomass three weeks after treatment. At the rates tested, sulfentrazone was more injurious to snap bean than pyroxasulfone. For instance the most frequent response to sulfentrazone was seedling death. Nonetheless, several entries were not affected by either herbicide. Results of GWAS models identified several chromosomal regions associated with snap bean response, including in order of significance chromosomes 11, 4, 7, 6, 5, and 9 for sulfentrazone, and chromosomes 2, 3, 4, and 6 for pyroxasulfone. A one million base pair region of chromosome 4 was common for snap bean response to sulfentrazone. This region of snap bean also had synteny with an ABC transporter gene in soybean (Glyma19g01940.1) which is associated with tolerance to herbicides inhibiting protoporphyrinogen oxidase. While interesting, these data are preliminary; the experiment will be repeated in 2020 with 375 snap bean entries.

Using Rimsulfuron Tank Mixes to Extend Residual Control of Pindar GT in Southeast Orchards. Christopher Holmberg*, Wayne E. Mitchem; North Carolina State University, Mills River, NC (369)

Using Rimsulfuron Tank Mixes to Extend Residual Control of Pindar®GT in Southeast Orchards. W.E. Mitchem and C. Holmberg. N.C. State University. Mills River, NC. Pindar GT is a premix herbicide of penoxsulam and oxyfluorfen, which is marketed by Corteva AgriScience. Oxyfluorfen is a desirable partner for penoxsulam because it controls certain weed species important in the western United States. The oxyfluorfen component restricts Pindar GT use, allowing applications only after completion of final harvest through fruit tree bud swell, which is restrictive for herbicide application uses in the Southeastern United States. The use of rimsulfuron tank mixes may provide extended control in the summer following an earlier application of Pindar GT. In 2019 we conducted a trial in a peach orchard located in Lincoln County, NC. Treatments consisted of penoxsulam + oxyfluorfen (Pindar GT) applied at 0.022 + 1.12 kg ai ha^{-1} or 0.035 + 1.68 kg ai ha^{-1} alone followed by an application of rimsulfuron at 0.07 kg ai ha^{-1}, or tank mixed with either diuron at 1.8 kg ai ha^{-1} or oryzalin at 2.24 kg ai ha^{-1}. Two additional treatments consisted of penoxsulam + oxyfluorfen at 0.022 + 1.12 kg ai ha^{-1} or 0.035 + 1.68 kg ai ha^{-1} tank mixed with oryzalin at 2.24 kg ai ha^{-1} followed by rimsulfuron at 0.07 kg ai ha^{-1} + oryzalin at 2.24 kg ai ha^{-1}. Indaziflam applied sequentially at 0.05 kg ai ha^{-1} as a comparison treatment. All herbicides were applied with a CO2 pressurized backpack sprayer calibrated to deliver 187 L ha^{-1} at 276 kPa. The sprayer was fitted with TeeJet 11002 XR nozzles and all herbicides were applied as a directed spray. The initial herbicide application was made April 1, 2019 and the second application was made on June 17, 2019. Herbicide efficacy was evaluated visually. On the July 18th evaluation, all of the initial herbicide treatments provided 97 % or higher control of *Plantago lanceolate*. All treatments provided 100% control of *Polygonum aviculave* except for penoxsulam + oxyfluorfen at 0.022 kg ai ha^{-1} + 1.12 kg ai ha^{-1} fb rimsulfuron at 0.07 kg ai ha^{-1}, which provided 90% control. *Digitaria sanguinalis* control was 93% or greater with most treatments, while penoxsulam + oxyfluorfen at 0.022 kg ai ha^{-1} + 1.12 kg ai ha^{-1} fb rimsulfuron at 0.07 kg ai ha^{-1} + oryzalin or rimsulfuron at 0.07 kg ai ha^{-1} provided 83% and 76 % control of *Digitaria sanguinalis*, respectively. On August 23rd all treatments provided 100% control of *Polygonum aviculave* with the exception of penoxsulam + oxyfluorfen at 0.022 + 1.12 kg ai ha^{-1} fb rimsulfuron at 0.07 kg ai ha^{-1} provided 96% control. All treatments provided 97% control or better of *Digitaria sanguinalis* with the exception of penoxsulam + oxyfluorfen at 0.022 kg ai ha^{-1} + 1.12 kg ai ha^{-1} fb rimsulfuron at 0.07 kg ai ha^{-1} + oryzalin and rimsulfuron at 0.07 kg ai ha^{-1} providing 90 and 84% control, respectively.

Penoxsulam+Oxyfluorfen For Residual Weed Management in Western Pecans. Jesse M. Richardson*[1], William B. McCloskey[2]; [1]Corteva Agriscience, Mesa, AZ, [2]University of Arizona, Tucson, AZ (370)

Effective weed management is crucial for maximizing nut quality in Western pecans, particularly in the early years of tree establishment. Two studies were established in San Simon, Arizona in 2018 and 2019 comparing the efficacy of a single spring preemergence herbicide application concept with a dormant plus early summer application concept. Herbicide treatments were applied with a tractor-mounted boom at a spray volume of 20 gallons of water per acre in orchards owned by A&P Pecans and FICO. Each study consisted of 8 chemical treatments arranged in a randomized complete block design, with 6 replications per treatment. Individual plots were 1800 ft^2 in size. At both sites, the second application in the dormant plus early summer application regimes was Pindar® GT (penoxsulam+oxyfluorfen) applied at 3 pints of product/acre (1.5 lb a.i./acre). Results suggested that the single spring treatment regimes were inferior to the dormant plus early summer application concepts. In plots treated with glyphosate without a pre-emergence herbicide, weeds reinfested the plots soon after application. ™®Trademark of Dow AgroSciences, DuPont or Pioneer, and their affiliated companies or respective owners

Efficacy of Preemergent Herbicides in Watermelon Production on Bareground Vs. a Cereal Rye Cover. Matthew B. Bertucci*[1], Amanda McWhirt[1], Alden Hotz[2], Lesley B. Smith[2]; [1]University of Arkansas, Fayetteville, AR, [2]University of Arkansas, Alma, AR (371)

Field studies were conducted in Alma, AR to evaluate performance of pre-transplant applications of three herbicides for use in watermelon in bareground and cereal rye cover production systems. Treatments were arranged in a split-plot with cover as the whole plot factor and herbicide as the split plot factor. Cereal rye was drill-seeded in September of 2018 and terminated in March of 2019 using a roller crimper and application of glyphosate. Herbicide treatments were applied on April 29, 2019 included *S*-metolachlor (1,014 g a.i. ha^{-1}), fomesafen (175 g a.i. ha^{-1}), and clomazone (280 g a.i. ha^{-1}) + ethalfluralin (896 g a.i. ha^{-1}). 'Exclamation' triploid watermelon were initiated in the greenhouse and transplanted at the 2 to 3-leaf stage into the field one day after herbicide applications. Data were collected on control of goosegrass (*Eleusine indica* L. Gaertn.) and Palmer amaranth (*Amaranthus palmer* S. Watson), weed biomass, watermelon fruit count, and yield. In cover crop plots, weed populations were too low to conduct ANOVA; instead, data were analyzed only from the bareground plots, in response to herbicide treatments. In bareground plots, *S*-metolachlor exhibited the greatest control of goosegrass (95 to 100%) and Palmer amaranth (85 to 94%), and exhibited the lowest accumulation of weed biomass. Cover crop had an overwhelming effect on watermelon fruit counts and on yield, relative to the effects of residual herbicides. Thus, ANOVA were conducted separately for herbicide treatment levels within each level of cover crop, despite a lack of significant interaction of cover crop with herbicide. Highest yields and fruit counts were observed in plots with cereal rye and treated with fomesafen, *S*-metolachlor, or no herbicide. Results indicate that preemergent herbicides are not sufficient for season-long weed control in watermelon and that cereal rye cover crops can minimize weed infestation and maximize yields relative to bareground production.

Novel Weed Management Tools for Horticulture Production in Florida. Ramdas Kanissery*; University of Florida, Immokalee, FL (372)

Weed management is a crucial component in Southwest Florida's horticulture production. The weather and soil conditions in the region promote rapid weed growth and make weed management a challenging task for citrus and vegetable producers. Concerns related to non-judicious use of herbicides, which include ground and surface water contamination, lack of herbicide efficacy on certain tolerant weed species, etc., have sparked a need for novel and alternative systems for weed management. We tested the possibility of using 'steaming' as an alternative weed management strategy in citrus production. A weed steamer was developed, and several steam treatments were utilized to control the growth of weeds in a citrus grove. Based on the observations from this study, the steam application has the potential to be included in a less chemical and integrated strategy for weed management in citrus tree rows. Additionally, in an ongoing project at the University of Florida's Southwest Florida Research and Education Center (SWFREC), we are evaluating the effectiveness of anhydrous ammonia as a pre-plant fumigant for controlling weeds in raised plastic mulched beds for vegetable production.

Growth and Reproductive Response of Vidal Blanc Grapes to Dicamba. Sarah E. Dixon*, Reid Smeda; University of Missouri, Columbia, MO (373)

Rising adoption of dicamba-tolerant soybeans increases the potential exposure of grapes to dicamba, where off-target injury may occur via particle or vapor drift. In 2017 and 2018 at three locations in Missouri, research in production vineyards focused on the single-season effects of dicamba on French-American hybrid grapes ('*Vidal blanc*'). During flowering and early fruit set, established grapes were exposed to low rates of dicamba, delivered as a spray solution (36 or 72 ppm) or by vapor from treated soil. The severity of dicamba injury (leaf cupping and feathering) was similar at 2 of 3 site years, with greater injury related to particle versus vapor drift of dicamba. Across all site years, season-long shoot growth was reduced up to 86% following exposure to particle drift. Minimal shoot inhibition resulted from dicamba vapor. At harvest, impacts of dicamba on grape yield were variable. At 2 of 3 sites, grape yield was reduced from dicamba as particle or vapor drift, with evidence for increased sensitivity during flowering. Across all site years, the final sugar content of berries at harvest was reduced by dicamba as particle drift up to 12%. Grapes are highly sensitive to dicamba, with visual symptoms extending throughout the growing season. Impacts of dicamba on berry sugar and yield may result from early-season injury.

Invasions of a New Species, Alkaliweed (*Crussa truxillensis*) in Orchards of California. Anil Shrestha*[1], James Schaeffer[1], Kurt J. Hembree[2]; [1]California State University, Fresno, Fresno, CA, [2]University of California Cooperative Extension, Fresno, CA (374)

Alkaliweed (*Cressa truxillensis*) a native perennial plant species of California has been invading agricultural areas in recent years. Heavy infestations of this species have been reported in perennial crop orchards. Standard orchard floor management practices such as cultivation and herbicides have had limited or no success on its control. There is very limited information available in literature about this species. Therefore, it is important to develop information on the biology and ecology of this species that can contribute to planning for its management. Studies were conducted to assess seed germination of this species at a range of pH, water potential, and salinity conditions. The growth and development of this species in response to various levels of shade was also assessed. Results showed that this species was adapted to a wide range of pH conditions, was fairly tolerant to drought, and highly tolerant to salinity during germination. However, the plants were not very shade tolerant. It is predicted that it has the potential to invade larger areas but may not be very competitive under low light conditions.

Grape (*Vitis vinifera*) Response to 2,4-D Choline Applied as a Directed Spray in Vineyards. Wayne E. Mitchem*[1], Kira C. Sims[2], Christopher Holmberg[1], Katherine M. Jennings[3]; [1]North Carolina State University, Mills River, NC, [2]North Carolina State University, Goldsboro, NC, [3]North Carolina State University, Raleigh, NC (375)

Grape is known to be very sensitive to 2, 4-D and through the years there have been many incidence of grape damage as a result of 2, 4-D drift and volatilization into vineyards. The development of 2, 4-D choline (Embed) has resulted in the expanded use of 2, 4-D in stone fruit crops and evaluations for its potential use in small fruit crops. In 2018 research conducted in North Carolina showed *Vitis rotundifolia* (Muscadine grape) to have excellent tolerance to 2, 4-D choline applied as a directed application contacting vine trunks in the herbicide strip. In 2019 a trial was conducted in Surry County, NC at an established Vinifera grape vineyard at Surry Community College. The variety in the planting was "Albarino". Treatments consisted of 2, 4-D choline applied at 0.5, 1, 1.6, and 2.1 kg ha^{-1} as a single application and as sequential applications. The single application was applied June 28 as was the initial application for treatments having a sequential application. On July 22 the sequential application was applied. A non-treated control was included for comparison. The test design was a randomized complete block with 4 replications. Individual plots consisted of 4 vines and data was collected from the two center vines. All treatments, including the non-treated control, received a standard herbicide application in addition to the 2,4-D choline treatments so weed competition would not impact results. 2, 4-D choline was applied as a directed spray into a 0.91 m weed-free strip, directly contacting vine trunks. The herbicide application was made using a CO_2 pressurized backpack sprayer fitted with a 11002 flat fan nozzle delivering 187 L ha^{-1} at 276 kPa. The test design was a randomized complete block with 4 replications. Means were separated using Fisher's protected LSD ($p \leq 0.05$). Visual estimates of phytotoxicity were made at 1, 2, 4, and 8 weeks after application. Grape yield and cluster weight data was collected as well as juice quality characteristics including pH, titratable acidity, and brix. Grape injury did not exceed 1% for any treatment therefore showing excellent crop tolerance to directed applications of 2, 4-D choline. Grape yield and cluster weight was not affected by 2, 4-D choline. Juice quality was not affected either. There were no differences in juice pH, titratable acidity, and brix. Results from this trial are consistent with results from the trial conducted in 2018 on *Vitis rotundifolia*. Results from this trial indicate *Vitis vinifera* has excellent tolerance to 2, 4-D choline applied as a directed spray beneath vines in the weed-free strip.

Effective Management of Yellow Nutsedge in Onion Depends on Herbicides Used in Preceding Crop Rotations. Joel Felix*[1], Joey Ishida[1], George Newberry[2]; [1]Oregon State University, Ontario, OR, [2]Gowan Company, Boise, ID (376)

There are relatively fewer herbicides registered for weed management in many specialty crops compared to agronomic crops. Consequently, growers often take advantage of the wider array of herbicides available for use in agronomic crops grown in rotation to manage weed species that are difficult to control in vegetable crops. Yellow nutsedge (*Cyperus esculentus L.)* has become a major weed problem in many agricultural fields in the Treasure Valley of eastern Oregon and southwestern Idaho. The severity and negative effects of yellow nutsedge are especially noticeable when fields are planted to direct-seeded onion (*Allium cepa* L.). Onion yield loss of 42% or greater or abandonment of field sections at harvest is not uncommon. A field study was conducted from 2015 to 2019 to demonstrate gains in yellow nutsedge control with crop rotations that utilize herbicides with proven effectiveness. The rotational crops and corresponding herbicides were; field corn (*Zea mays* L.) in 2015 and 2016 [glyphosate, halosulfuron, s-metolachlor, dimethenamid-p, EPTC, prepackaged rimsulfuron plus thifensulfuron-methyl, and prepackaged halosulfuron plus thifensulfuron-methyl], dry bean (*Phaseolus vulgaris* L.) in 2017 [EPTC, dimethenamid-p, ethalfluralin, and trifluralin], wheat (*Triticum aestivum* L.) in 2018 [prepackaged bromoxynil plus 2, 2-methyl-chlorophenoxyacetic acid], and onion in 2019 [dinethenamid-p applied through drip irrigation]. An untreated control was included (treated with dimethenmid-p through drip irrigation in 2019). Herbicides used in crops grown in rotation from 2015 to 2017 (corn/corn/dry bean) reduced yellow nutsedge tubers by 80-93% across different treatments compared to 50% for the untreated control. Tubers were reduced further by wheat competition in 2018 resulting in substantially few tubers at the time of onion planting in 2019. The reduction in tubers during the winter wheat phase in 2018 could be exclusively attributed to the full ground-cover, which negatively affected yellow nutsedge growth and in turn produced fewer to no additional tubers. No onion injury was observed from herbicides used in preceding years. Marketable onion yield ranged from 67,827 to 88,013 kg/ha across herbicide treatments compared to 64,745 kg/ha for the untreated control (treated with dimethenamid-p through drip irrigation in 2019). The results indicated improved management of yellow nutsedge with crop rotations and corresponding herbicides.

WSWS PROJECT 3: WEEDS OF AGRONOMIC CROPS

WSSA SECTION 1: AGRONOMIC CROPS

Glyphosate and AMPA Persistence and Distribution in Soils Under Field Conditions in the Midwestern USA. Robert J. Kremer*; University of Missouri, Columbia, MO (288)

Abstract not available

Developing a Predictive Yield Loss Model for Sensitive Soybeans Exposed to Dicamba. Jerri Lynn Henry*[1], Reid Smeda[1], Jason Weirich[2]; [1]University of Missouri, Columbia, MO, [2]Affiliation Not Specified, Columbia, MO (289)

Off-target damage attributed to dicamba has been an agronomic issue since the release of dicamba-tolerant (DT) crops in 2017. Injury to sensitive crops have been reported to agriculture agencies, with approximately 1,400 cases reported nationwide in 2019. A number of reports linked yield losses in sensitive soybeans to dicamba have been published, but development of a more refined model is needed, especially for low rates of dicamba. This purpose of this study was to quantify yield reductions associated with dicamba exposure and to generate models that can be used to quantify yield losses based of dicamba visual injury ratings commonly used by weed scientists. Yields losses ranged from 9.6 to 48.2% with 25 and 300 ppm dicamba, respectively. Soybeans exposed to dicamba at the R1 growth stage exhibited yield reductions significantly greater than soybeans exposed to the same rate at the V3 growth stage. Model statements were generated to predict yield reduction based on visual injury ratings 21 days after dicamba exposure (0-100 scale); (r^2=0.7945). This study suggests a model can predict soybean yield loss following in-season exposure to dicamba, which can improve upon current yield loss techniques.

Implications of Dicamba and 2,4-D Tank Contamination Across Enlist and Xtend Soybean Varieties. Bryan G. Young*[1], N. Cade Hayden[2], Matthew Osterholt[2], Mandy Bish[3], Kevin W. Bradley[3], Shawn P. Conley[4], William G. Johnson[2], Greg R. Kruger[5], Jason K. Norsworthy[6], Daniel B. Reynolds[7], Larry Steckel[8]; [1]Purdue University, Brookston, IN, [2]Purdue University, West Lafayette, IN, [3]University of Missouri, Columbia, MO, [4]University of Wisconsin-Madison, Madison, WI, [5]University of Nebraska-Lincoln, North Platte, NE, [6]University of Arkansas, Fayetteville, AR, [7]Mississippi State University, Mississippi State, MS, [8]University of Tennessee, Jackson, TN (290)

The commercialization of soybean resistant to 2,4-D (Enlist) and dicamba (Xtend) has increased the likelihood of sensitive soybean exposure to these herbicides. The developers of 2,4-D- and dicamba-resistant soybean have stated that no cross resistance across these soybean traits and herbicides exists due to rapid and specific metabolism of the enabled herbicide. However, the potential may exist for low concentrations of these herbicides from tank contamination to result in a synergistic response in soybean if applied with a full rate of the enabled herbicide before complete metabolism can occur. Field experiments were conducted from 2016 through 2019 to determine: 1) the response of glyphosate-resistant soybean to dicamba and 2,4-D, 2) the influence of a full rate of dicamba applied with tank-contamination doses of 2,4-D on the response of Xtend soybean, and 3) the influence of a full rate of 2,4-D applied with tank-contamination doses of dicamba on the response of Enlist soybean. Herbicides were applied to soybean at the V2 or R1 growth stage. Xtend soybean sensitivity to 2,4-D was similar to glyphosate-resistant soybean, with a range of 5 g ae ha^{-1} in the ED_{10} values for soybean injury 14 DAT, across the V2 and R1 growth stages. Yield reduction was also similar between soybean types, with an ED_{10} value of 34 g ha^{-1} of 2,4-D pooled across the V2 and R1 exposure timings. Aside from injury at 14 DAT, the response of Xtend soybean to simulated 2,4-D tank-contamination in any other data parameters collected was not influenced by the presence of a full rate of dicamba. Additionally, simulated 2,4-D tank-contamination did not affect Xtend soybean seedling progeny grown from parent plants in this study in commercial seed testing or greenhouse assays. Similar to the results on Xtend soybean, the application of a full rate of 2,4-D on Enlist soybean did not influence soybean response to dicamba as a tank contaminant. These results indicate that the resistance-mechanisms for Xtend and Enlist soybean are extremely robust, offer no cross-resistance across these auxin herbicides, and the resistance traits are not compromised by accidental exposure from tank contamination of the non-enabled auxin herbicide.

Dicamba Rate Influences on Fruiting in Sensitive Cotton. Kyle R. Russell*[1], Peter A. Dotray[2], Irish L. B. Pabuayon[1], Glen L. Ritchie[1]; [1]Texas Tech University, Lubbock, TX, [2]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX (291)

The adoption of dicamba-tolerant cotton (*Gossypium hirsutum* L.) has increased the number dicamba applications to aid in the control of troublesome weeds including glyphosate-resistant Palmer amaranth (*Amaranthus palmeri* S. Wats). More dicamba applications increases the risk of off-target movement to non-target crops. A field study was conducted at the Texas Tech University New Deal Research Farm in 2017 and 2018 to evaluate cotton response to dicamba at four crop growth stages (first square + two weeks, first bloom, first bloom + two weeks, and first bloom + 5 weeks). Dicamba (Clarity 4L) at 0.56 (1X), 0.056 (1/10X), 0.0112 (1/50X), 0.0056 (1/100X), and 0.00112 (1/500X) kg ae/ha was applied at 140 l/ha using TTI11004 nozzles. Plots, four 102-cm rows by 9.1 m, were replicated three times in a subsurface irrigation field. The field study was kept weed-free for the entire growing season. Cotton was box mapped prior to harvest to determine boll number and distribution as affected by treatment. Each boll was recorded by fruiting site, and bolls were weighed in cohorts corresponding with first position bolls between nodes 4 and 8, nodes 9 through 11, and nodes 12 and above. Second position bolls were grouped with first position bolls two nodes higher based on the similarity of blooming dates on the plant. Plots were machine harvested to determine lint yield and fiber analysis was determined at the Texas Tech University Fiber and Biopolymer Institute. When applications were made at first square + two weeks, a shift in boll distribution was apparent following dicamba at 1/50X in 2017 and at 1/10X in 2018 when compared to the non-treated control. A shift in boll distribution from the 1/50X dicamba rate was apparent at the first bloom application in 2017, but not in 2018. When applications were made at first bloom + two weeks, boll number was reduced following dicamba at 1X. Relative to the non-treated weed-free control, no change in boll number and position was apparent following any dicamba rate when applied at first bloom + five weeks in either 2017 or 2018. Dicamba at 1/500X, 1/100X, and 1/50X did not affect yield at any application timing when compared to the non-treated control. When dicamba was applied at 1/10X, the greatest yield loss was observed when dicamba was applied at first square + two weeks followed by first bloom and first bloom + two weeks. Micronaire increased following dicamba at 1/10X when applied at first square + two weeks, first bloom, and first bloom + two weeks in 2017. In 2018, micronaire decreased following dicamba at 1/10X when applied at first bloom + five weeks. Shifts in boll production have the potential to influence fiber quality and lint production; however, dicamba at =1/50X did not affect fiber quality or lint production.

Influence of Carrier Water Characteristics and Adjuvants on Dicamba Volatilization in a Controlled Environment. Matthew Osterholt*[1], Hayden C. Hayden[1], Julie M. Young[2], Manoj S. Ghaste[1], William G. Johnson[1], Joshua R. Widhalm[1], Bryan G. Young[2]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, Brookston, IN (292)

The commercialization of dicamba-resistant soybean (Glycine max (L.) Merr.) has increased the potential for off-target dicamba movement to sensitive crop species. While application restrictions continue to expand on how dicamba may be applied to dicamba-resistant soybean, a broader understanding of the factors that influence off-target movement, especially volatility drift, is well desired. As a result, controlled environment experiments were conducted to quantify the effects of

1) spray additives sold as drift reduction agents, 2) spray solution ions that may be found in water supplies used as spray carrier, 3) a range of spray solution pH, and 4) suspended soil in carrier water on the relative volatilization of three dicamba formulations. The diglycolamine (DGA), diglycolamine with VaporGrip® (DGA + VG), or N,N-Bis-(3-aminpropyl)methylamine (BAPMA) salts of dicamba were applied to dicamba-resistant soybean at a rate of 560 g ae ha^{-1} and placed into a closed chamber for 48 h while sampling the air for dicamba vapor. The addition of drift reduction agents resulted in no increase of dicamba volatilization in comparison to the dicamba applied for all three formulations. In addition, applying dicamba in turbid carrier water, from suspended high organic matter or high clay soil in the spray solution, did not result in increased volatilization compared with dicamba alone. At a spray solution pH of 3.0, dicamba volatilization was increased 2.8X and 3.9X for the DGA + VG and BAPMA formulations, respectively, compared with each respective dicamba formulation applied alone with no pH adjustment (pH 5.4 to 6.4). However, spray solution pH levels of 4, 5, and 6 were not different from dicamba alone for the BAPMA and DGA + VG formulations. Diammonium sulfate and ferrous sulfate in the carrier water resulted in volatilization increases of at least 5X and 9X, respectively, compared with each dicamba formulation applied alone. In conclusion, this research suggests that the addition of drift reduction agents and turbid carrier water do not contribute to dicamba volatility. Additionally, spray solution pH levels from 4 through 6 does not increase dicamba volatility when applied to soybean leaf surfaces. When considering equal concentrations of cations found in water supplies, the presence of iron and ammonium can increase dicamba volatility independent of any change in spray pH. A crucial implication of this research is the influence of the previously mentioned factors when applied to soybean leaf surfaces, which may differ when applied to soil or glass surfaces.

Dicamba Research Update. Thomas C. Mueller*[1], Larry Steckel[2]; [1]University of Tennessee, Knoxville, TN, [2]University of Tennessee, Jackson, TN (293)

This report details data from field and lab studies from 2017, 2018 and 2019. The field studies utilized high-volume air samplers located inside the treated area. The samplers were operated over a time course of 0 to 36 hours after treatment. Dicamba emissions were greater during the afternoon hours compared to nighttime. A three-year field study of DGA dicamba applied to various surfaces showed more dicamba coming from green plants than tilled soil than dead plants. Relative responses of the three years were consistent, but the overall magnitude of dicamba measurement varied by a factor of 20X. The measured temperature and relative humidity of the three surfaces were similar, so another explanation will be needed. This surface effect is important, since most of the reported field studies of dicamba emission are under bare ground conditions, and as such could be understating actual dicamba concentrations. A comparison of DGA, DGA +Vapor Grip (VG), and BAPMA salts of dicamba; all treatments including the potassium salt of glyphosate; showed that the DGA tended to have slightly higher emissions, but the three treatments had similar overall dicamba emissions. Lab studies indicated that the addition of glyphosate to DGA+VG greatly increased dicamba emissions. Dicamba emissions were also directly related to temperature, with little volatility at 15 C, but more dicamba as the temperature increased. The addition of glyphosate to dicamba mixtures reduced final pH substantially, often below label recommendation of 5.0. This was true for both BAPMA and DGA+VG over a wide range of starting water pHs.

The addition of AMS had only a minor effect on pH, indicating that total cationic loading was an important factor in the subsequent dicamba volatility. BAPMA and DGA+VG spray mixture pH was not affected by potential tank mix partners of clethodim, glufosinate, acetochlor, S-metolachlor and bifenthrin.

Influence of pH Buffers on Volatility of Dicamba Tank Mixtures. Ryan D. Langemeier*, Steve Li, Katilyn J. Price, Frances B. Browne; Auburn University, Auburn, AL (294)

Dicamba tolerant crops allow for application well into the growing season, during warmer weather which favors volatility. Dicamba volatility may increase when dicamba and glyphosate are tank mixed as glyphosate lowers the pH of the spray solution. Therefore, increasing spray solution pH with pH buffering products may reduce dicamba volatility when utilizing dicamba/glyphosate tank mixtures. A trial was designed with the objective of determining the effect of pH buffering agents on dicamba volatility. Seven commercial products with buffering ability were titrated into herbicide solution of dicamba (Engenia) herbicide at 560 g ai ha^{-1}, and glyphosate (Roundup Powermax II) at 1540 g ai ha^{-1}, and Intact drift reduction agent at 0.5% v/v to create titration curves. From the seven commercial buffers four were field tested in conjunction with four citrate buffers with pH's of 3.0, 4.0, 5.0, and 6.0 were. Field testing consisted of spraying soil flats with herbicide tank mixed with a buffer, a non-treated control, and chemical control which did not include a buffer product. Two soil flats per plot were then placed under open low tunnels which straddled two rows of sensitive soybeans for 48 hours. Air sampler readings were recorded from the chemical control as well as the 4.0, 5.0, and 6.0 citrate buffers. Visual injury ratings of soybeans were recorded at 7, 14, 20, and 28 days after treatment (DAT). Following the field study, a greenhouse trial was designed to evaluate the efficacy of the herbicide buffer mixtures using morningglory *(Ipomoea sp.)*, tillage radish *(Raphanus sativus)*, and annual ryegrass *(Lolium multiflorumas)* as assay plants. Treatments used in the field study, with an additional high pH treatment (pH 8.38), were diluted to 1/3 rates of the field trial. Visual injury ratings were recorded at 14 and 28 DAT and biomass was collected at 28 DAT. The addition of glyphosate lowered the pH of a solution of dicamba and Intact from 6.5 to 4.7. All commercial buffers increased pH to above 5.0. Soybeans injury at 20 DAT under the low tunnels is negatively correlated with increasing spray solution pH (R^2=.73). All commercial products reduced visual injury in the field trial. In the greenhouse trial, a trend was observed for reduced injury relative to the chemical control as pH increased when using the citrate buffers. In general, the trend was not statistically significant. Injury to tillage radish at 28 DAT was reduced 18% and 22.5% relative to the chemical control for commercial buffers with pH's 5.17 and 5.69. However, injury relative to the chemical control was only reduced by 13.75% and 7.5% for commercial products with pH's of 6.86 and 6.89. Our results indicate that buffer products may be a tool to reduce volatilization when using dicamba tank mixes. The lack of relationship between pH of herbicide solution and herbicide efficacy for commercial products implies that buffers may need to be evaluated individually for effects on herbicide efficacy.

Greenhouse Evaluation of Suspected Resistance to XtendiMax® Herbicide with VaporGrip® Technology as Part of the Conditions of Registration. Daljit Singh*[1], Sean Evans[2], Jeffrey E. Herrmann[3], Chandrashekar Aradhya[1]; [1]Bayer Crop Science, Chesterfield, MO, [2]Bayer Crop Science, Jacksonville, IL, [3]Bayer Crop Science, Creve Coeur, MO (295)

The dicamba formulation (M1768) commercially available as XtendiMaxÒ with VaporGripÒ technology is approved for over-the-top use in dicamba-tolerant soybean and cotton crops by U.S. EPA (Environmental Protection Agency) with certain conditions of registration (EPA registration number 524-617). One of the conditions stipulates the requirement for investigation and appropriate follow-up of product performance inquiries (PPIs) in instances where a lack of efficacy by XtendiMax is observed under field conditions. Weed populations meeting the criteria set forth in Norsworthy, et al. (2012) were subsequently sampled and tested in a controlled environment with assay results reported to the US EPA in an annual report. In 2018 and 2019, weed seed samples from surviving weeds were collected from 19 and 27 grower fields, respectively. Species represented in these weed populations included waterhemp, Palmer amaranth, kochia, velvetleaf, and marestail. The testing was conducted in a controlled environment at the Bayer Crop Science research facility in Chesterfield, Missouri. Treatments consisted of either 560g ae ha^{-1} and/or 1120g ae ha^{-1} applied to approximately four-inch weeds. The objective of this study was to assess suspected resistance to XtendiMax in a controlled environment. Individual plants were visually rated for mortality at approximately 21 days after treatment (DAT). In both years, 100% mortality was observed for all populations at 1120 g ae/ha rate of XtendiMax at 21 DAT. At the 560g ae ha^{-1}, the surviving plants, if any, exhibited significant injury and/or stunted growth compared to untreated controls. Based on greenhouse results in both the years of testing, none of the tested populations were suspected to have resistance to XtendiMax. These fields are closely monitored in collaboration with the growers, and recommendations are provided for resistance management strategies.

Engenia Herbicide for 2020. Tracy Rowlandson*; BASF, Raleigh, NC (296)

Paper withdrawn

Enlist E3TM Soybean Weed Control and Crop Tolerance. David M. Simpson*; Corteva, Indianapolis, IN (297)

First sales of Enlist E3® soybean seed occurred in 2019 enabling the use of Enlist® weed control system to control glyphosate susceptible and resistant weeds in U.S. soybean fields. Enlist E3 soybean contains a single molecular stack of *aad-12, pat* and *2mepsps* genes which conveys tolerance to 2,4-D choline, glufosinate and glyphosate. Enlist Duo® with Colex-D® technology is a 0.95:1 premix containing 2,4-D choline 195 g ae/L and glyphosate 205 g ae/ha with a recommended use rate of 1640 and 2185 g ae/ha. Enlist One® with Colex-D Technology contains 2,4-D choline 456 g ae/L with the recommended use rate being 800 to 1065 g ae/ha. Enlist One should be tank mixed with either glyphosate or glufosinate for control of grass and broadleaf weeds. The recommended spray volume for Enlist Duo or Enlist One plus glyphosate is 94 to 187 L/ha. Both Enlist One and Enlist Duo contain Colex-D Technology that results in less potential for physical drift and near zero volatility of 2,4-D. When the Colex-D Technology is matched with approved nozzles, the percentage of driftable fines can be reduced by 90% compared to traditional 2,4-D formulations and nozzles. In contrast to dicamba products, the volatility potential for Enlist One and Enlist Duo herbicides is not affected by the addition of ammonium sulfate, glyphosate or glufosinate. For optimum weed control and resistance management, Corteva recommends starting clean prior to planting, apply two effective site of action residual herbicides prior to crop emergence and then apply either Enlist Duo or Enlist One plus glufosinate or glyphosate when weeds are four inches or less. Residual herbicides approved for use with Enlist One and Enlist Duo can be included in the postemergence application to extend the residual control of *Amaranthus* species. Only tank mix with products that are listed on www.enlisttankmix.com website for Enlist One and Enlist Duo. A sequential postemergence application of Enlist Duo or Enlist One plus glyphosate or glufosinate can be applied with a minimum of 12 days between applications. In 2019, over million acres of Enlist E3 soybean were treated with either Enlist Duo or Enlist plus glufosinate or glyphosate with no off-target movement issues reported to Corteva. Since 2013, the programs of preemergence residual herbicides followed by Enlist Duo or Enlist One plus glufosinate or glyphosate has provided greater than 90% weed control in university soybean trials across the US. Enlist E3 soybean with the Enlist weed control system provide growers with options for controlling glyphosate resistant broadleaf weeds. "®™Trademarks of Dow AgroSciences, DuPont, or Pioneer and their affiliated companies or respective owners. Enlist E3® soybean technology is jointly developed by Dow AgroSciences LLC and MS Technologies LLC."

PPO-resistant *Amaranthus* Species Control in XtendFlex® Soybeans. Neha Rana*[1], Blake Barlow[2], Ryan E. Rapp[3], Rod Stevenson[4]; [1]Bayer Crop Science, St Louis, MO, [2]Bayer Crop Science, Hallsville, MO, [3]Bayer CropScience, Mitchell, SD, [4]Bayer Crop Science, Lansing, MI (298)

Glyphosate-resistant Amaranthus species were detected in the mid 2000's and since then growers have relied upon protoporphyrinogen oxidase- (PPO) inhibitor herbicides for weed control in soybean and cotton. With the heavy reliance upon PPO-inhibitor chemistry, Amaranthus species were selected with resistance to PPO-inhibiting herbicides over the last decade. XtendiMax® herbicide with VaporGrip® Technology and Liberty® herbicide provides effective sites of action (SOA) to control PPO-inhibitor-resistant weed species. Pending regulatory approval, XtendFlex® Soybeans confer tolerance to glyphosate, glufosinate and dicamba. In 2019, fifteen field trials were conducted in IN, IL, MO, TN, MN, MD, and NC to evaluate control of PPO-inhibitor-resistant weed species in XtendFlex® Soybeans. Eleven of these trials were conducted with university academics on sites with confirmed PPO-inhibitor-resistant weed populations. Results from field trials indicate that effective residual herbicides applied preemergence at planting (PRE) and postemergence (POST) with XtendiMax® herbicide with VaporGrip® technology or Early POST followed by POST application of Liberty® herbicide provided excellent control of glyphosate and PPO-resistant weeds. XtendiMax® herbicide with VaporGrip® Technology is part of the Roundup Ready® Xtend Crop System and is a restricted use pesticide. Commercialization of XtendFlex® soybeans is dependent on multiple factors, including successful conclusion of the regulatory process. The information presented herein is provided for educational purposes only, and is not and shall not be construed as an offer to sell. XtendFlex® soybeans have received full approval for planting in the United States but are pending approval in certain export markets. For 2020, XtendFlex® soybeans will be available as part of a stewarded introduction only to growers who have signed a 2020 XtendFlex® Stewardship Agreement and agree to follow the stewardship requirements.

Control of Multiple-herbicide-resistant Waterhemp in Corn. Christian A. Willemse*[1], Peter H. Sikkema[1], Amit J. Jhala[2], Darren E. Robinson[1], David C. Hooker[1]; [1]University of Guelph, Ridgetown, ON, Canada, [2]University of Nebraska-Lincoln, Lincoln, NE (343)

Multiple-herbicide-resistant (MR) waterhemp is becoming increasingly difficult to control due to the evolution of resistance to herbicide Groups 2, 5, 9 and 14. Field studies were conducted in Ontario in 2018 and 2019 to determine if MR waterhemp can be effectively controlled with 4-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibiting herbicides applied postemergence (POST), and if two-pass herbicide programs provide greater and more consistent control of MR waterhemp than single-pass programs in corn. The control of MR waterhemp with the HPPD-inhibiting herbicides isoxaflutole, mesotrione, topramezone, tembotrione and tolpyralate with and without the addition of atrazine was evaluated. At 4 WAA, the addition of atrazine to isoxaflutole, mesotrione, topramezone and tembotrione improved MR waterhemp control from 71 to 86, 81 to 92, 79 to 86 and 90 to 97%, respectively. Tolpyralate controlled waterhemp 90% which was not increased with the addition of atrazine. Single- and two-pass programs for MR waterhemp control were evaluated in one study by applying isoxaflutole + atrazine, s-metolachlor/mesotrione/bicyclopyrone/atrazine and tolpyralate + atrazine preemergence (PRE), with and without a POST application of glufosinate. A second study evaluated waterhemp control by applying s-metolachlor + atrazine, saflufenacil/dimethanamid-p and dicamba/atrazine PRE, with and without mesotrione + atrazine POST. At 4 WAA, isoxaflutole + atrazine and tolpyralate + atrazine, followed by POST applications of glufosinate, increased MR waterhemp control from 90 to 97 and 84 to 96%, respectively. At 8 WAA, s-metolachlor/atrazine and dicamba/atrazine, followed by POST applications of mesotrione + atrazine, increased MR waterhemp control from 95 to 99 and 88 to 99%, respectively. Saflufenacil/dimethanamid-P PRE provided 98% MR waterhemp control and was not increased by a POST application of mesotrione + atrazine. This research identifies effective and consistent single- and two-pass herbicide programs for MR waterhemp in corn in Ontario.

Does Amplification of the *EPSPS* Gene Alone Confer Glyphosate Resistance in Common Waterhemp. Balaji Aravindhan Pandian*, Sanzhen Liu, P.V. Vara Prasad, Tesfaye Tesso, Mithila Jugulam; Kansas State University, Manhattan, KS (344)

The evolution of glyphosate resistance in common waterhemp across the US Midwest has been a great challenge for growers, especially in Roundup Ready cropping systems. Amplification of 5-enolpyruvylshikimate-3-phosphate synthase (*EPSPS*) gene, the molecular target of glyphosate has been reported in several glyphosate-resistant common waterhemp populations. Our previous research documented the amplification of the *EPSPS* gene at the native locus closer to the pericentromeric region. However, some glyphosate-resistant individuals also showed the presence of *EPSPS* copies in an extra circular chromosome termed “Extra Circular Chromosome carrying Amplified EPSPS (ECCAE)." Nonetheless, the possible influence of any other genetic elements associated with ECCAE in imparting glyphosate resistance in common waterhemp is not known. The objective of this research was using a genomics approach, examine if any other genes, along with *EPSPS* are amplified in common waterhemp. The whole genome of three common waterhemp plants with varying *EPSPS* copies, classified as high-(HR), moderate-(MR), and low-resistant (LR) to glyphosate along with a known susceptible (GS) was sequenced using Illumina

HiSeq2500. The genome sequence of all the four samples were aligned to waterhemp reference genome V2. Gene copy number variation of glyphosate-resistant plants was calculated relative to the read count of the susceptible plant. Florescent *in-situ* hybridization (FISH) was performed to physically map the amplified genes. The whole-genome sequence analyses suggest that multiple genes (up to 40 genes) flanking *EPSPS* were also amplified along with *EPSPS* in HR, while only the transketolase (*TKT*) gene, located close to the *EPSPS* was amplified in all glyphosate-resistant, i.e., LR, MR and HR plants. Further, FISH mapping of six amplified genes flanking *EPSPS* confirmed that the multiple genes amplified in HR plants appear to be located in the ECCAE. Whereas, in MR and LR plants, both *TKT* and *EPSPS* found to be amplified near the native locus, with no ECCAE. The association of multi-gene amplification with ECCAE was also validated in several F_1 plants generated from a cross between HR x GS. Although still elusive, these results suggest a possible role of *TKT* in the evolution of glyphosate resistance and the formation of ECCAE in common waterhemp. Overall, it appears that the formation of ECCAE via breakage-fusion-bridge mechanisms along with *EPSPS* and other genes is a classic example of the rapid evolution of adaptive traits in common waterhemp.

Control of Glyphosate-Resistant Canada Fleabane with Three-Way Tankmixes in Soybean.
Peter H. Sikkema*, Nader Soltani; University of Guelph, Ridgetown, ON, Canada (345)

Inconsistent control of glyphosate-resistant (GR) Canada fleabane in soybean in Ontario has been obtained with currently recommended herbicides. Eight field trials (2 in 2016, 3 in 2017, 3 in 2018) were conducted in farmers' fields in southwestern Ontario with heavy infestations of GR Canada fleabane to evaluate the efficacy of glyphosate (900 g ae ha^{-1}) + saflufenacil (25 g ai ha^{-1}), 2,4-D ester (500 g ai ha^{-1}) or paraquat (1100 g ai ha^{-1}) applied preplant (PP) as 2-way tankmixes, or in 3-way tankmixes with sulfentrazone (140 g ai ha^{-1}), flumioxazin (107 g ai ha^{-1}) or metribuzin (400 g ai ha^{-1}) for the control of GR Canada fleabane in GR soybean. Glyphosate + saflufenacil applied PP provided as much as 90% GR Canada fleabane control. The addition of sulfentrazone, flumioxazin or metribuzin to the tankmix provided as much as 93, 96 and 97% control of GR Canada fleabane, respectively. Glyphosate + 2,4-D ester applied PP provided as much as 59% GR Canada fleabane control. The addition of sulfentrazone, flumioxazin or metribuzin to the tankmix provided as much as 60, 59 and 91% GR Canada fleabane control, respectively. Glyphosate + paraquat applied PP provided as much as 85% GR Canada fleabane control. The addition of sulfentrazone, flumioxazin or metribuzin to the tankmix provided as much as 88, 89 and 98% GR Canada fleabane control, respectively. Density and biomass reductions of GR Canada fleabane with herbicides evaluated followed the same pattern as weed control evaluations. Soybean yield was reduced by 66% due to GR Canada fleabane interference. Soybean yield was similar to the weed-free control with all the herbicide treatments evaluated. Based on these results, glyphosate + saflufenacil, glyphosate + 2,4-D ester or glyphosate + paraquat tankmixed with metribuzin can provide effective GR Canada fleabane control in GR soybean.

Horseweed (*Erigeron canadensis*) Growth Stage Response to Herbicide Technologies. Aaron Froemke*[1], Kirk A. Howatt[2]; [1]North Dakota State University, Lisbon, ND, [2]North Dakota State University, Fargo, ND (346)

Horseweed (*Erigeron canadensis*) is a competitive winter or summer annual broadleaf weed that has evolved resistance to numerous herbicide sites of action. In North Dakota, horseweed typically emerges and produces a rosette in late fall, vernalizes during winter months, then bolts in early spring. Greenhouse and field experiments were conducted to evaluate horseweed growth stage response to herbicide and fall application timing. Greenhouse results determined horseweed control was greatest when herbicide was applied to early rosette horseweed, providing an average of 70% control. Horseweed control decreased by 36 and 29% when applied to late rosette and bolting plants, respectively. Field results determined that sole applications of dicamba or paraquat controlled existing plants but lacked residual for control of later emerging horseweed, resulting in less than 77% control the following spring. When flumioxazin was added with dicamba or paraquat, percent control increased to 99% the following spring. The added residual benefit flumioxazin provided helped to control later emerging plants. Saflufenacil applied alone controlled existing plants while providing long enough residual to control later emerging horseweed resulting in 99% control the following spring as well. Horseweed must be controlled when it is young and vulnerable. Addition of residual herbicides in a fall herbicide application significantly increased control of late emerging winter annual horseweed. These fall-applied herbicide applications will allow soybean growers to spend more time planting in early spring rather than controlling horseweed. Additional research must be done to investigate efficacy of other fall-applied residual herbicides for horseweed control.

A Kochia Population with Possible Field Resistance to Dicamba, Fluroxypr and Glyphosate. Randall S. Currie*[1], Patrick Geier[1], Chandrima Shyam[2], Mithila Jugulam[2]; [1]Kansas State University, Garden City, KS, [2]Kansas State University, Manhattan, KS (347)

Abstract not available

Characterizing Response of Glyphosate-, Dicamba-, and Fluroxypyr-Resistant Kochia to Atrazine and Metribuzin. Rui Liu*[1], Vipan Kumar[1], Randall S. Currie[2], Patrick Geier[2], Taylor Lambert[1], Phillip W. Stahlman[1]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Garden City, KS (348)

Two kochia accessions (KS-4A and KS-4H) were recently identified from a corn field near Garden City, KS with multiple resistance to glyphosate, dicamba, and fluroxypyr. The objective of this research was to determine the response of these kochia accessions to PRE and POST applied atrazine and metribuzin. The progeny seeds obtained from plants of both accessions that survived field-use rate (1120 g ha $^{-1}$) of POST atrazine were used. In addition, seeds of a known susceptible kochia accession (SUS) collected from research fields in Hays, KS were also used. Greenhouse experiments were conducted at Kansas State University Agricultural Research Center near Hays, KS. For PRE atrazine and metribuzin dose-response assays, plastic trays (25.4 cm by 25.4 cm) containing field soil were used. Separate dose-response assays were carried out in a completely randomized design with four replications. One hundred seeds from each accession were separately sown on the soil surface of each tray. Doses of PRE atrazine and metribuzin herbicides, including 0, 1/4X, 1/2X, 1X, 2X, and 4X (1X of atrazine=1120 g ha^{-1}; 1X of metribuzin=630 g ha^{-1}) were tested. Emerged kochia seedlings from all three accessions at each tested herbicide dose were counted at 28 days after treatment (DAT). For POST atrazine and metribuzin dose response assays,

experiments were separately conducted using 10 cm by 10 cm plastic pots in a randomized complete block design with 12 replications. Same doses of both herbicides tested in PRE dose-response study were utilized in POST dose-response assays. Data on percent visible injury and shoot dry weights were collected at 21 DAT. Results indicated that the effective dose (ED_{50} values) of PRE applied atrazine required for 50% reduction in seedling emergence of KS-4A, KS-4H, and SUS was 4506, 245, and 33 g ha^{-1}, respectively, indicating 135- and 7- fold resistance in both putative accessions. Furthermore, the KS-4A and KS-4H accessions exhibited 18- and 14-fold resistance to POST applied atrazine, as compared to SUS accession. The KS-4A and KS-4H accessions had >95% survivors with PRE and POST applied field-use rate of metribuzin at 21 DAT. Partial sequence analysis of the *psb*A gene (~550 bp region) revealed a single, target-site Ser264Gly point mutation in the KS-4A and KS-4H accessions. In conclusions, these results suggest that multiple resistant kochia accessions from Garden City, KS are also resistant to PRE and POST applied atrazine and metribuzin and single-point mutation (Ser264Gly) confers the high-level resistance to these triazine herbicides.

Heat Stress and Recurrent Herbicide Application May Speed the Evolution of Junglerice Tolerant to Florpyrauxifen-benzyl. Lariza Benedetti[1], Nilda Roma-Burgos[2], Luis A. Avila*[1]; [1]Universidade Federal de Pelotas, Pelotas, Brazil, [2]University of Arkansas, Fayetteville, AR (349)

Heat Stress and Recurrent Sublethal Herbicide Application May Speed the Evolution of Junglerice Resistance to Florpyrauxifen-benzyl Lariza Benedetti[1], Gulab Rangani[2], Luis Antonio de Avila[1], Pâmela Carvalho de Lima[2], Nilda Roma-Burgos[2] [1]Federal University of Pelotas; Crop Protection Graduate Program; Pelotas, RS, Brazil [2]University of Arkansas; Crop, Soil and Environmental Sciences; Fayetteville, AR, US Abstract. The intensive use of herbicides exerts high selection pressure on weeds. Resistance to herbicides in *Echinochloa colona* (junglerice) is increasing globally and this may be exacerbated by climate change. Heat stress is one of the major environmental factors that can affect food production and weed control. The objectives of this research were to: 1) study the combined effect of heat stress and recurrent selection with sublethal dose of florpyrauxifen-benzyl on the evolution of junglerice resistance to herbicide and 2) investigate some candidate stress-adaptation genes. The experiment was conducted in a completely randomized design with six replications in the greenhouse, in 1-L pots, containing one plant per pot. Factor A was junglerice generation (G0-original population SS; G1 and G2 were progenies of recurrent selection). Factor B was herbicide treatment (florpyrauxifen-benzyl at 3.125 g ai ha^{-1}, which corresponds to 0.125x the recommended dose, and non-treated check). Factor C was heat stress (30 and 45°C). Three weeks after herbicide application, junglerice control was evaluated visually on a scale of 0% (no symptoms) to 100% (dead). A dose-response assay was conducted to assess any increase in tolerance level from G0 to G2. The expression of *trehalose phosphate phosphatase* (*TPP*), *trehalose phosphate synthase* (*TPS*) and *UDP-glucosyltransferase* (*UGT*) was quantified in G0 and G2 plants by qRT-PCR before and 12 h after herbicide application. The control of junglerice at 30 °C did not differ between G0 and G2; however, junglerice control declined from G0 to G2 at 45 °C. The expression of *TPP* and *TPS* did not differ between 30 °C and 45 °C 12 h after herbicide treatment. On the other hand, *UGT* transcripts increased 28-fold at 45°C 12 h after florpyrauxifen application, on G2 plants compared to G0. This suggests the involvement of *UGT* in alleviating the effects of florpyrauxifen-benzyl and heat stress; hence possibly facilitating adaptation to these stresses. Overall, the data support the hypothesis that heat stress can accelerate the adaptation of junglerice to sublethal doses of some herbicides such as flopyrauxifen-benzyl. Global warming may exacerbate weed resistance evolution to herbicides in regions most affected by this environmental change.

Evaluation of Herbicide Resistance in Diverse Palmer Amaranth and Waterhemp Populations in the USA. Alejandro Perez-Jones*[1], Rong Ma[1], Chenxi Wu[2], Chandrashekar Aradhya[1]; [1]Bayer Crop Science, Chesterfield, MO, [2]Bayer CropScience, St Louis, MO (350)

Herbicide resistance has become prevalent in Palmer amaranth and waterhemp, two problematic weeds in soybean, cotton, and corn in the U.S. High selection pressure by glyphosate, PSII, ALS, PPO, and HPPD inhibitors led to the selection of resistant populations to these herbicides. The introduction of new technologies, including Liberty Link®, Roundup Ready® Xtend, and Enlist® has led to an increased use of glufosinate, dicamba, and 2,4-D, respectively, which increases selection pressure and can potentially lead to resistance to these herbicides. Hence, it is important to evaluate herbicide sensitivity in diverse Palmer amaranth and waterhemp populations to establish a baseline for herbicide efficacy. This presentation will summarize the results of several greenhouse studies on the performance of dicamba, glufosinate, and 2,4-D on multiple Palmer amaranth and waterhemp seed samples collected across the U.S.

Investigation of Herbicide-resistant Redroot Pigweed (*Amaranthus retroflexus*) Populations in North Carolina. Eric A. Jones*, Wesley Everman, Ramon G. Leon; North Carolina State University, Raleigh, NC (351)

In 2017, a farmer reported a redroot pigweed (*Amaranthus retroflexus*) population in Yadkin County, NC not being controlled with glyphosate applications. Initial screenings provided evidence that putative lethal rates of glyphosate were not providing greater than 60% control, on average. Further screenings indicated this redroot pigweed population was surviving putative lethal rates of imazethapyr, but was being controlled with atrazine and lactofen. In 2019, a different farmer reported a redroot pigweed population in Camden County, NC not being controlled with lactofen and imazethapyr applications. Greenhouse dose-response assays were conducted to determine if the both redroot pigweed populations had evolved resistance to imazethapyr and if the Yadkin County redroot pigweed population had evolved resistance to glyphosate. Imazethapyr was applied along a log 10 scale with rates ranging from 0.7 to 7000 g ai ha^{-1}. Glyphosate was applied along a log 3.16 scale with rates ranging from 10 to 1000 g ai ha^{-1}. The Camden County redroot pigweed population never incurred injury greater than 10% with all tested rates of imazethapyr. The Yadkin County redroot pigweed population incurred variable injury at all tested rates of imazethapyr, but there was evident survival at rates exceeding a putative lethal rate. The Yadkin County redroot pigweed population expressed differential susceptibility to glyphosate when compared with a herbicide-susceptible redroot pigweed population. However, the rates that the Yadkin County redroot pigweed population survived were considered a sub-lethal rate. Thus, the results of the experiment provide evidence of imazethapyr-resistant redroot pigweed and the Yadkin County redroot pigweed population is in the early stages of evolving resistance to glyphosate.

Synthetic Auxins and Glufosinate Applied Sequentially for Control of Palmer Amaranth and Associated Physiological Response. Frances B. Browne*, Steve Li, Katilyn J. Price, Ryan D. Langemeier; Auburn University, Auburn, AL (352)

Insufficient residual herbicide activation can lead to palmer amaranth escapes in row crop production. Glufosinate is effective on small Palmer amaranth. However, aggressive growth and adverse weather conditions can complicate timely applications and salvage programs are frequently sought. In order to investigate the influence of sequence and timing of dicamba and glufosinate applications on large Palmer amaranth control, field and greenhouse studies were conducted in 2018 and 2019. Field studies were performed in Henry County, AL. Treatments were applied to Palmer amaranth 35 to 60 cm tall. Herbicides tested were dicamba, glyphosate, glufosinate, and *S*-metolachlor at 559 g, 1.54 kg, 594 g, and 1.47 kg ai ha^{-1}. One-time applications evaluated were dicamba + glyphosate, glufosinate + *S*-metolachlor, and a 4-way tank mixture. Sequential applications included dicamba + glyphosate followed by (fb) glufosinate + *S*-metolachlor 3 or 7 days after initial treatment (DAIT) in addition to the reverse sequence at a 7 day interval. Visual injury was recorded at 14 and 28 DAIT in addition to height and biomass 35 DAIT. Palmer amaranth control following dicamba programs varied between years. Sequential applications of dicamba + glyphosate fb glufosinate + *S*-metholachlor 7 DAIT resulted in complete mortality in 2018 and 42% biomass reduction in 2019 as compared to the nontreated control. Time intervals between sequential applications at 3 and 7 days did not influence Palmer amaranth control. Greenhouse studies were performed in 2019 on Palmer amaranth 20 to 40 cm tall. In addition to a nontreated control, treatments included a 4-way mix of dicamba + glufosinate + *S*-metolachlor + glyphosate, dicamba + glyphosate fb *S*-metolachlor + glufosinate 7 DAIT, and glufosinate + *S*-metolachlor fb dicamba + glyphosate 7 DAIT applied at 1/3 of rates used in the field study. Photosynthetic accumulation, was recorded at 1, 4, 6, 8, 11, 13, and 35 DAIT. Leaf tissue was removed 14 DAIT, weighed, and regrowth was evaluated 21 days later. Compared to the nontreated control, initial applications that included glufosinate reduced photosynthetic accumulation 90 to 96% 1 DAIT. Treatments of dicamba + glyphosate only reduced photosynthetic accumulation by 22%. Photosynthetic accumulation did not differ for any treatment by 14 DAIT suggesting complete recovery. Vegetative biomass 14 DAIT was reduced for all treatments relative to the nontreated control. However, dicamba + glyphosate fb glufosinate + *S*-metolachlor 7 DAIT was the only treatment to result in reduced regrowth vegetation 35 DAIT by 48%. Glufosinate impaired Palmer amaranth photosynthesis at a larger magnitude as compared to dicamba. Strategic applications of the synthetic auxins and glufosinate may reduce Palmer amaranth recovery potential. Palmer amaranth infested fields are more likely to be rescued with sequential applications of dicamba fb glufosinate than when applied alone or in tank mixtures.

Waterhemp (Amaranthus tuberculatus) and Palmer Amaranth (*Amaranthus palmeri*) Control in a Glyphosate, Glufosinate, and Dicamba Resistant Soybean Variety. Travis Legleiter*[1], J. D. Green[2]; [1]University of Kentucky, Princeton, KY, [2]University of Kentucky, Lexington, KY (353)

Glyphosate-resistant *Amaranthus tuberculatus* and *Amaranthus palmeri* are wide spread across the state of Kentucky and remain the predominate weed problem for many Kentucky soybean producers. In addition to wide spread glyphosate resistance, PPO-resistance has now also been confirmed in these species in Kentucky. This has further emphasized a need for diverse herbicide programs to not only control existing resistant weeds, but also in mitigating future resistance. Producers previously relied heavily on soil residual herbicides followed by a limited number of postemergence options to control these weeds. The number of postemergence options has expanded in the last two years with the introduction of dicamba-tolerant soybean and will be further expanded in the near future with a new generation of soybean with combined tolerance to glyphosate, dicamba, and glufosinate. Field Studies evaluating preemergence and postemergence herbicide combinations in a glyphosate-, dicamba-, and glufosinate-soybean variety were conducted in 2018 and 2019 at five Kentucky locations with infestations of glyphosate resistant-*A. tuberculatus or A. palmeri.* A factorial arrangement was used to evaluate preemergence herbicides followed by postemergence herbicide combinations in a randomized complete block design with four replications at each site. Preemergence herbicides included pyroxasulfone, pyroxasulfone plus flumioxazin, and S-metolachlor plus metribuzin plus fomesafen in 2018; a non-preemergence treatment was added in 2019. Postemergence combinations included: dicamba, glufosinate, dicamba followed by glufosinate, dicamba plus acetochlor, and glufosinate plus acetochlor in 2018; a tank mix glyphosate plus glufosinate was added to the evaluation in 2019. Visual evaluations 21 days after preemergence application showed greater control with the preemergence applications with three sites of action than the single site of action preemergence application. *Amaranthus* densities per 3m^2 collected at the end of the season did not show a significant interaction of preemergence and postemergence factors at all sites and years. Analysis of preemergence and postemergence treatment factors revealed that *Amaranthus* densities at the end of the season were influenced by preemergence applications with the multiple site of action treatments having greater density reduction than the single site of action preemergence treatments and/or treatment not receiving a preemergence application. Postemergence applications following preemergence treatments did not have an influence on *Amaranthus* densities. Results from these studies highlight the flexibility of the multiple effective postemergence options in this new generation of soybeans while emphasizing the importance of the continued use of multiple site of action preemergence products to control these two *Amaranthus* species.

The Importance of Glufosinate for Managing Palmer Amaranth (*Amaranthus palmeri*) in Auxin-Based Herbicide Systems. Grace F. Flusche Ogden*[1], Peter A. Dotray[2], John Everitt[3]; [1]Texas Tech University, Lubbock, TX, [2]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX, [3]Bayer - US Crop Science, Shallowater, TX (354)

Dicamba and 2,4-D tolerant cotton systems provide new opportunities to manage glyphosate-resistant populations of Palmer amaranth (*Amaranthus palmeri*). Adding glufosinate in these auxin-based systems may not only improve management of troublesome weeds, but aid against rapid development of herbicide resistance to WSSA Group 4 modes of action. Two studies were conducted near Lubbock, Texas at the Texas A&M AgriLife Research and Extension Center in 2018 and 2019 to evaluate the efficacy of glufosinate in dicamba and 2,4-D choline weed management systems. Trials were conducted in a non-crop environment with dense populations of Palmer amaranth (70 per m^2). One trial consisted of sequential applications of glufosinate (Liberty® 280 SL) and dicamba (XtendiMax® with VaporGrip Technology®). Palmer amaranth at the initial application was <10 cm, 10 to 20 cm, and >30 cm in size. In a second trial, sequential applications of glufosinate (Liberty® 280 SL), 2,4-D choline (Enlist One® with Colex-D® technology) or 2,4-D choline + glyphosate (Enlist Duo® with Colex-D ® technology) were used and Palmer amaranth at the initial application was 7 to 15 cm and 25 to 30 cm in size. Sequential applications were made 10 to 11 days after the initial application in both trials. Applications were made using a CO_2-pressurized backpack sprayer at a volume of 140 L ha^{-1}. Dicamba and 2,4-D treatments were sprayed with Turbo TeeJet Induction 11002 nozzles while all glufosinate treatments were sprayed with Turbo TeeJet 11002 nozzles. Ammonium sulfate at 2.86 kg ai ha^{-1} was added to all glufosinate applications. Treatments were applied at the following rates: dicamba 0.56 kg ae ha^{-1}, 2,4-D choline 0.80 kg ae ha^{-1}, 2,4-D choline + glyphosate 1.62 kg ae ha^{-1}, and glufosinate 0.88 kg ai ha^{-1} for all initial applications and those that followed an auxin application, or 0.59 g ai ha^{-1} following an initial application of glufosinate. When evaluated 21 days after the sequential application, all treatments in the dicamba trial controlled <10 cm Palmer amaranth at least 86%. Replacing an application of dicamba with glufosinate resulted in similar weed control when compared to two applications of dicamba. When evaluated 11 days after the sequential application, treatments of 2,4-D + glyphosate in the initial sequential application controlled 7 to 15 cm Palmer amaranth at least 89%, which was similar to the control following glufosinate followed by (fb) 2,4-D + glyphosate. Two applications of glufosinate or treatments with 2,4-D choline alone in the initial application were less effective at controlling Palmer amaranth when compared to 2,4-D choline + glyphosate fb 2,4-D choline + glyphosate or glufosinate. In each trial, replacing an application of an auxin herbicide with glufosinate resulted in similar weed control when compared to two applications of the auxin herbicide. The use of glufosinate adds an alternative mode of action in an auxin-based system and should help sustain these new auxin-technologies from rapid development of herbicide resistance.

Efficacy of a New Fluroxypyr + Arylex Active Weed Control Product in Wheat. Mike Moechnig*[1], Jeffery Krumm[2], Joe Yenish[3], Bruce Steward[4], Patti Prasifka[5], Dave Johnson[6], Mike Lovelace[7]; [1]Corteva Agriscience, Brookings, SD, [2]Corteva Agriscience, Hastings, NE, [3]Corteva Agriscience, Billings, MT, [4]Corteva, Oklahoma City, OK, [5]Corteva Agriscience, West Fargo, ND, [6]Corteva Agriscience, Eagan, MN, [7]Corteva Agriscience, Lubbock, TX (355)

Pixxaro™ EC is a new broadleaf herbicide containing fluroxypyr and Arylex™ active (halauxifen methyl). Arylex active, a new active ingredient from Corteva Agriscience, is a novel synthetic auxin (WSSA group 4) herbicide from the arylpicolinate chemical class being developed for all global cereal markets including the U.S. The recommended use rate of Pixxaro EC herbicide is 6 fl oz/A (fluroxypyr 123 g ae/ha + Arylex 5.3 g ae/ha) that may be applied in wheat, barley, and triticale. Field research was conducted in ND, SD, MT, ID, WA, KS, NE, and OK from 2014-2019. Pixxaro EC resulted in 92% kochia (*Bassia scoparia*) control, which was similar to that of WideMatch® herbicide when averaged over 20 trials. However, in trials focused on early (2-4 in tall kochia) and late (4-8 in tall kochia), Pixxaro EC averaged approximately 7% greater kochia control than WideMatch. These results demonstrate Pixxaro EC provides greater kochia control consistency relative to WideMatch. Pixxaro EC also provided control (80% or greater) of common lambsquarters (*Chenopodium album*) and pigweed (*Amaranthus*) species, whereas WideMatch only provided suppression (less than 80%) of these species. Pixxaro EC only provided suppression of several *Brassicaceae* species, but these species could be controlled by tank mixing with 2,4-D.

In summary, field research results demonstrated Pixxaro EC controls a wide-range of difficult to control broadleaf weeds, including kochia, in spring cereals. ™®Trademark of Dow AgroSciences, DuPont, or Pioneer, and their affiliated companies or their respective owners.

Assessment of Potential Allelopathic Effects of Pacific Northwest Winter Wheat Cultivars on Annual Weeds. Haifeng Xing[1], Steve Young*[2]; [1]Inner Mongolia Agricultural University, Hohhot City, China, [2]Utah State University, Logan, UT (356)

Abstract not available

Efficacy and Crop Safety of a New Broadleaf Herbicide for Northern Plains Cereals Containing, Clopyralid, Halauxifen-methyl, and Fluroxypyr. Joe Yenish*[1], Patti Prasifka[2], Dave Johnson[3], Mike Moechnig[4]; [1]Corteva Agriscience, Billings, MT, [2]Corteva Agriscience, West Fargo, ND, [3]Corteva Agriscience, Eagan, MN, [4]Corteva Agriscience, Brookings, SD (357)

Arylex™ active (halauxifen methyl) is a novel synthetic auxin (WSSA group 4) herbicide from the arylpicolinate chemical class being developed by Corteva Agriscience™ for all global cereal markets including the U.S. WideARmatch™ herbicide is a newly proposed premix of Arylex, fluroxypyr-meptyl, and clopyralid-olamine with a target use rate of 14 to 19.6 fl oz/A [Arylex (halauxifen methyl 5.0 to 7 g ae/ha) + fluroxypyr-meptyl (125 to 175 g ae/ha) + clopyralid-olamine (100 to 140 g ae/ha)] that will be registered in wheat (including durum), barley and triticale. This herbicide offers a unique broadleaf weed control spectrum on annual and perennial species for cereals producers. Field research was conducted during the 2018 and 2019 cropping seasons at multiple locations across ND, SD, and MT to evaluate WideARmatch efficacy and crop safety in spring wheat. WideARmatch was applied with and without tank-mix partners such as 2,4-D ester. WideARmatch provided excellent control of redroot pigweed (*Amaranthus retroflexus*), common lambsquarters (*Chenopodium album*), wild buckwheat (*Polygonum convolvulus*), marestail (*Conyza canadensis*) and kochia (*Bassia scoparia*). Relative to WideARmatch alone, the tank mix with 2,4-D ester increased control of waterhemp (*Amaranthis tuberculatis*) and Russian thistle (*Salsola iberica*). There was little to no spring wheat response to WideARmatch, indicating excellent crop safety. WideARmatch herbicide with Arylex will provide cereal growers with a new tool for controlling many difficult to control broadleaf weeds, including herbicide resistant biotypes of kochia and waterhemp. ™®Trademark of Dow AgroSciences, DuPont, or Pioneer, and their affiliated companies or their respective owners.

Feral Rye (*Secale cereale*) Control and Economics with ACCase Tolerant Wheat Production System in Colorado. Eric P. Westra*, Todd A. Gaines; Colorado State University, Fort Collins, CO (358)

Field trials were conducted in 2018-19 to evaluate rye (*secale cereale*) control and economic returns with the ACCase tolerant wheat production system in Colorado. The field study was established as a split-plot design with rye density as whole-plot factor and herbicide treatment as the split-plot factor. Feral rye was established at five different densities (0,5,15,25 and 50%) based on standardize wheat planting density of 60 lbs acre^{-1}. Quizalofop p-ethyl was applied in the fall, early spring, and late spring at both 10 and 12 fl oz acre^{-1}, as well as a fall and spring split application of 8 and 8 fl oz acre^{-1}. Herbicide applications were applied with a CO_2 pressurized

backsprayer calibrated at 20 gallons acre^{-1}. All plots were harvested for wheat yields, and subsamples were used to calculate the percentage of rye dockage. Adverse weather affected late spring applications (extended freezing temperatures the day after application) and yield (significant hail event 13 days before harvesting). Net economic returns were calculated using seed and herbicide costs, wheat yields at current Colorado wheat prices, and averaged Colorado dockage payment penalties. Economic returns from herbicide applications were only statistically greater than the untreated check when rye was at or above 15% density. The greatest economic return in higher rye density scenarios (15,25, and 50%) tended to be from fall and early spring applications where earlier removal of rye competition, relative to late spring applications, increased yields and net returns. Net economic returns from the best herbicide treatment compared to untreated check plots resulted in a 1.37, 2.23, and 2.0-fold increase for rye densities at 15, 25, and 50%, respectively. When averaged across all herbicide treatments, there was a correlation between rye density and net returns, with higher rye densities having lower net economic returns. Results from this study will be used to help provide growers best management recommendations to maximize weed control efficacy and economic returns from the ACCase tolerant wheat production system in Colorado.

Four Seasons of Italian Ryegrass (*Lolium perenne* Ssp. *multiflorum*) Management in Oklahoma Winter Wheat. Misha R. Manuchehri*, Justin T. Childers, Hannah C. Lindell, Lane S. Newlin; Oklahoma State University, Stillwater, OK (359)

The integration of delayed PRE herbicides in Oklahoma winter wheat may improve the control of acetolactate synthase and acetyl CoA carboxylase resistant Italian ryegrass [*Lolium perenne* L. spp. *multiflorum* (Lam.) Husnot]. Studies were conducted at the Cimarron Valley Research Station at Perkins, OK on a sandy loam during the 2016-17, 2017-18, and 2018-19 seasons to evaluate weed management systems that included flufenacet + metribuzin, metribuzin, pinoxaden, and pyroxasulfone applied alone or in tank mixture at the delayed PRE and/or POST timings. Visual weed control, crop injury, and yield were evaluated. In all three years, the only treatments that achieved greater than 90% control were those that included flufenacet + metribuzin or pyroxasulfone + metribuzin applied DPRE followed by pinoxaden POST or pyroxasulfone + metribuzin + pinoxaden DPRE. Due to the cost of these tank mixtures, they seldom will be applied in Oklahoma wheat. Flufenacet + metribuzin or pyroxasulfone applied DPRE alone are more realistic options and provided 90 to 97% control during the 2018-19 season when timely rains were received following application. During the 2017-18 season, control was only 70% following either delayed PRE herbicide treatment as adequate rains were not received until five weeks after application. Conversely, during the 2016-17 season, 7 cm of rain was received within one week of application, which reduced the effectiveness of the delayed PRE herbicides, especially flufenacet + metribuzin compared to pyroxasulfone. Delayed PRE herbicides are a viable Italian ryegrass management option in Oklahoma winter wheat; however, it is critical that they are applied strategically and should accompany cultural practices such as crop rotation.

Is Dichlorprop-p Less Antagonistic Than 2,4-D to Group 1 Herbicides in Wheat? Kirk A. Howatt*[1], Joseph Mettler[1], Paul O. Johnson[2], Bob Bruss[3]; [1]North Dakota State University, Fargo, ND, [2]South Dakota State University, Brookings, SD, [3]Nufarm Americas, Morrisville, NC (360)

The search for alternatives to control resistant biotypes of broadleaf weeds in wheat, such as kochia, is a perpetual activity. At times this brings our attention to view mature products in a new light. Dichlorprop has been used in lawn premixes to complement and supplement control with other auxinic herbicides. Trials were conducted in North Dakota to evaluate kochia control and antagonism of ACCase-inhibiting herbicide activity with dichlorprop-p in wheat. Dichlorprop-p at 8 oz ae/A provided similar kochia control 1 month after application (MAA) compared with 2 oz ae/A fluroxypyr, but progression of symptoms was more rapid with dichlorprop-p than fluroxypyr. Yellow foxtail control with fenoxaprop was antagonized by 2,4-D and sulfonylurea herbicides by 10 to 22 percentage points. Dichlorprop-P did not affect foxtail control with fenoxaprop except where other broadleaf herbicides also were included, which resulted in decreased control by up to 8 percentage points. Treatments with 2,4-D reduced fenoxaprop control of wild oat by as much as 15 percentage points 1 MAA. Dichlorprop-p did not reduce wild oat control 1 MAA except when another broadleaf herbicide was included. Slight antagonism, 6 points, of yellow foxtail control with pinoxaden resulted when mixed with 2,4-D or bromoxynil, but dichlorporp-p did not reduce pinoxaden control of yellow foxtail or wild oat. Flucarbazone control of yellow foxtail or wild oat was not affected by addition of dichlorprop-p or other broadleaf herbicides. Dichlorprop-p appears to have relevance for broadleaf weed control in small grains and use should be investigated and developed further.

The Extent of Herbicide Resistance in Key Weeds of the Southeastern Australian Grain Production Region. Christopher Preston*[1], John C. Broster[2], Peter Boutsalis[1], Gurjeet S. Gill[3]; [1]University of Adelaide, Glen Osmond, Australia, [2]Charles Sturt University, Wagga Wagga, Australia, [3]University of Adelaide, Adelaide, Australia (361)

Herbicide resistant weeds area a major constraint to field crop production in Australia. A survey of 1760 fields was conducted across southeastern Australia during 2013-2017 to collect seeds of weeds remaining in crop fields and test these for resistance to herbicides. Rigid ryegrass (*Lolium rigidum)* was collected from 82% of fields. Other weeds were less common. Wild oats (*Avena* spp.) was collected from 37% of fields, annual sowthistle (*Sonchus oleraceus*) from 28% of fields and brome grass (*Bromus* spp.) from 21% of fields. Herbicide resistance was common in rigid ryegrass with 85% of samples resistant to at least one herbicide, with resistance to acetolactate synthase (ALS)-inhibiting herbicides and acetyl-Coenzyme A carboxylase (ACCase)-inhibiting herbicides most common. Multiple resistance was also common in rigid ryegrass with 60% of samples resistant to at least two herbicide modes of action and one sample resistant to 5 herbicide modes of action. For annual sowthistle, 70% of samples collected had resistance to herbicides, primarily to ALS-inhibitors. For oriental mustard (*Sisymbrium orientale*), 45% of samples collected had resistance to at least one herbicide, mainly to ALS-inhibiting herbicides and phytoene desaturase (PDS)-inhibiting herbicides, with 13% resistant to two or more herbicide modes of action. For all other weeds, resistance was less common. This survey shows that herbicide resistance is common in several weed species in crop fields of southeastern Australia, dramatically reducing the herbicides available for control.

Herbicide Metabolism Affects Quizalofop Tolerance of CoAXium Wheat. Raven A. Bough*, Franck E. Dayan, Todd A. Gaines; Colorado State University, Fort Collins, CO (362)

Commercialized CoAXium winter wheat lines are characterized by two mutant acetyl-CoA carboxylase (ACCase) homoeologs that confer plant tolerance to the active form of quizalofop-p-ethyl herbicide. Despite the same pedigree, overall resistance and metabolism were previously shown to be greater for Incline AX compared to Fusion AX. We hypothesized that differences were due to distinct gene variants involved in herbicide metabolism, differential expression of metabolism genes, or a combination of aforementioned factors. To evaluate differences between CoAXium parental lines as well as to potentially identify the parental source of enhanced metabolism, sub-lethal doses of quizalofop were applied to susceptible parent lines and resistant single mutant homoeolog accessions. Active herbicide content in plant tissue over time was measured using liquid-chromatography mass-spectrometry (LC-MS). Notably, the parent Byrd exhibited quizalofop metabolism approximately 1.7 times faster than the parent Hatcher. The effect of temperature on quizalofop metabolism in both CoAXium lines was also evaluated by LC-MS. Anecdotal field observations suggested a difference in herbicide tolerance upon cold exposure immediately after treatment, however herbicide content was not significantly different between lines subjected to average and colder-than-average temperature regimes in controlled environments. Herbicide uptake across both lines did significantly differ between temperature regimes across time, where quizalofop content peaked at two days after treatment under the average temperature regime and at eight days after treatment in the colder-than-average regime. A separate dose-response study of Fusion and Incline AX with variable quizalofop doses in combination with one of three cytochrome P450 monooxygenase inhibitors was conducted. Fusion AX had a 50% growth reduction dose approximately 1.6 times greater than Incline AX when PBO was applied in tandem with herbicide. Results suggest resistance and metabolic differences between CoAXium lines may be related to differences in P450 enzyme function or expression likely derived from Byrd rather than Hatcher. Additionally, temperature does not disproportionately affect quizalofop metabolism in CoAXium lines.

Voraxor: A New Novel Herbicide for Grass and Broadleaf Weed Control in Australian Winter Cereals. Ian Francis*[1], Marco Montagna[2], Russell Ison[1], Gavin Heard[3]; [1]BASF Australia, Tamworth, Australia, [2]BASF Australia, Bannockburn, Australia, [3]BASF Australia, Melbourne, Australia (363)

VoraxorTM: a new novel herbicide for grass and broadleaf weed control in Australian winter cereals. Ian Francis, Marco Montagna, Russell Ison, Gavin Heard BASF Australia Ltd, Level 12, 28 Freshwater Place, Southbank, Victoria 3006, Australia (ian.francis@basf.com) Trifludimoxazin [1,5-dimethyl-6-thioxo-3-(2,2,7-trifluoro-3,4-dihydro-3-oxo-4-prop-2-ynyl-2H-1,4-benzoxazin-6-yl)-1,3,5-triazinane-2,4-dione] (Tirexor®) is a potent, novel inhibitor of protoporphyrinogen IX oxidase (PPO or Protox). Trifludimoxazin is very active when applied PRE or POST on dicotyledons/broadleaf weeds such as wild radish (Raphanus raphanistrum L.) and has also demonstrated activity on key monocotyledons/grass weeds including annual ryegrass (Lolium rigidum Gaud.). Voraxor herbicide has been developed using a combination of trifludimoxazin plus saflufenacil (1:2 ratio) which showed improved spectrum of burndown and residual weed control over either herbicide applied alone. Trifludimoxazin is expected to receive its first registration in Australia in 2020 for use in pre-plant burndown and pre-emergent residual weed control in winter cereals under the trade name of Voraxor herbicide. This registration will provide Australia cereal growers a valuable new tool in management of weeds including species resistant to alternate modes of action.

Non-Tolerant Wheat Response to Quizalofop-P-ethyl in Central Oklahoma. Justin T. Childers*[1], Misha R. Manuchehri[1], Vipan Kumar[2], Tyson Ochsner[1], Rui Liu[2], Hannah C. Lindell[1], Lane S. Newlin[1]; [1]Oklahoma State University, Stillwater, OK, [2]Kansas State University, Hays, KS (364)

CoAXium® wheat, a new production system, allows for the use of Aggressor™ herbicide [active ingredient: quizalofop-P-ethyl (quizalofop)] over-the-top of wheat. With the rise in hectares planted to the AXigen™ trait, the likelihood of physical drift or tank contamination or misapplication to nearby sensitive plants, including wheat that is not tolerant to quizalofop, may increase. To evaluate non-tolerant winter wheat response to quizalofop, studies were conducted during the 2018-19 and 2019-20 winter wheat growing seasons at three sites in central Oklahoma and one site in Hays, KS. Fall and spring treatments consisted of quizalofop at 1X, 1/10X, 1/50X, 1/100X, and 1/200X rates, where the 1X rate equaled 92 g ai ha^{-1}. Visual crop response was recorded every two weeks throughout the growing season and biomass and grain yield were collected at harvest. Biomass was collected from two 0.10 m^{-2} quadrats from each plot. At Lahoma, there was an application timing by rate interaction where wheat yield and biomass following the 1/10X rate were greater in the fall compared to the spring. At Perkins, herbicide rate affected both biomass and yield. Complete crop loss was observed following the 1X and 1/10X rates applied in the fall and spring. Additionally, yield following the 1/50X rate was less than the non-treated control, 1/100X, and 1/200X rates. Overall, regardless of location, yield loss was not observed following the two lowest rates, suggesting that the risk of crop loss due to tank contamination or misapplication is greater than the risk of physical drift.

Dichlorprop-p Combinations with Auxin Herbicides for Weed Control in Chemical Fallow. Philip Westra*[1], Kirk A. Howatt[2], Greg R. Kruger[3], Peter A. Dotray[4], Misha R. Manuchehri[5], Vipan Kumar[6], Bob Bruss[7]; [1]Colorado State University, Fort Collins, CO, [2]North Dakota State University, Fargo, ND, [3]University of Nebraska-Lincoln, North Platte, NE, [4]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX, [5]Oklahoma State University, Stillwater, OK, [6]Kansas State University, Hays, KS, [7]Nufarm Americas, Morrisville, NC (365)

Abstract not available

Dicotyledonous Weed Control with Pulse-Width Modulation (PWM) Technology. Kelly T. Satrom*, Kirk A. Howatt; North Dakota State University, Fargo, ND (366)

Pulse-width modulation (PWM) technology has been commercially available for many years, but recent industry recommendations to increase droplet sizes have increased use of PWM sprayers. Previous research in North Dakota has shown the potential for greatly reduced weed control as droplet size increases. In 2018 and 2019, field trials were conducted near Fargo, Galesburg, and Prosper, ND, to investigate different droplet sizes, travel speeds, and how they interact to affect control of broadleaf weed species with four herbicide combinations commonly used in wheat or soybean production systems. Treatments in all four studies included a factorial combination of

250, 400, 600, and 750 micron droplet sizes and 8, 16, and 24 km/h travel speeds applied with a pulse sprayer plus treatments of a handboom-sprayed and untreated checks. In wheat studies with bromoxynil and pyrasulfotole, control of weed species was reduced up to 20 percentage points as droplet size and travel speed increased. New technologies such as dicamba- and glufosinate-resistant soybean varieties require the use of more course droplet sizes; however, control was greater than 90% across treatments. For most treatments, droplet size and travel speed did not have a significant effect. However, within soybean and wheat trials data showed that faster ground speed and larger droplet size had a deleterious effect on common lambsquarters control. More research is needed to confirm results showing the interaction of droplet size and ground speed and how they affect efficacy of various herbicides.

Herbicides for Industrial Hemp Grain Production. Joseph Mettler*, Kirk A. Howatt; North Dakota State University, Fargo, ND (433)

In 2019, more than 59,000 hectares of hemp (*Cannabis sativa* L.) were grown in the United States, where there are no herbicides labeled for use in industrial hemp. Canadian producers only have quizalofop and ethalfluralin labeled for use. Several pre- and post-emergence herbicides were selected from greenhouse experiments and evaluated at 1x and 2x rates in the field. Experiments were conducted in 2019 and were established as a randomized complete block design (RCBD) with five replicates at four locations. Hemp was evaluated for crop safety, density, height, and yield. In the pre-emergence experiment, crop injury from pendimethalin, trifluralin, quinclorac, saflufenacil, and pyroxasulfone were similar to non-treated hemp. Trifluralin and saflufenacil at the 2x rates reduced plant density. Plant height, while different among treatments 21 days after planting, did not differ at harvest. Yield of hemp grain following herbicide was similar to the hand-weeded plots. Most post-emergence treatments resulted in significant hemp injury. Clopyralid resulted in 10% injury, with all other treatments above 30%. Height of plants treated with chloransulam and oxyflurorfen were 40-60% shorter than non-treated plants 70 days after application. Yield varied across locations due to a location by treatment interaction. Although the analysis of yield demonstrated a treatment by location interaction, neither bromoxynil nor clopyralid resulted in less yield at either location. Hemp was resilient to moderate herbicide injury (40%) and compensated for early season plant injury and reduced density. These experiments will be repeated in 2020 as more replicated data is necessary to aid in herbicide registration.

Common Ragweed (*Ambrosia artemisiifolia*) and Palmer Amaranth (*Amaranthus palmeri*) Control and Fecundity from POST Herbicides at Various Growth Stages with and without Fomesafen. Eric B. Scruggs*, Michael L. Flessner; Virginia Tech, Blacksburg, VA (434)

Common ragweed (*Ambrosia artemisiifolia* L.) is a problematic early-season weed in soybeans, decreasing yield up to 76%. Palmer amaranth (*Amaranthus palmeri* S.) is a troublesome weed due to its aggressive growth and prolific seed production. Both of these weeds are difficult to control, due to herbicide resistance, and control with effective herbicides is difficult at weed heights above 10 cm. Field studies were initiated with the overarching goal of mitigating PPO resistance by comparing POST herbicides in a non-crop system across various weed heights with and without fomesafen. Field studies were located in Lawrenceville and South Hill, VA in 2018 and in Blackstone and Blacksburg, VA in 2019. Studies investigated known glyphosate and ALS-resistant populations, although populations were PPO-susceptible. Studies utilized randomized complete block designs with four replications. Treatments consisted of the following alone and in combinations with fomesafen: mesotrione, dicamba, 2,4-D choline, glufosinate, glyphosate, and fomesafen (alone only). Herbicide treatments were standard labeled field rates and utilized adjuvants and nozzles as noted on product labels. Emerged weeds were counted and flagged according to size (5 to 10, 10 to 20, and 20 to 30 cm tall) prior to application. Data collected included visible control assessed on a 0 (no control) to 100 (plant death) scale 4 weeks after treatment (WAT) and seed production data on a per plant basis. All data were subjected to ANOVA and subsequent means separation using Fisher's Protected LSD (a=0.05). Where necessary, data were transformed to improve normality and back transformed data were presented. Contrast statements were created comparing effective (no resistance in population) herbicides (mesotrione, dicamba, 2,4-D, and glufosinate) alone and in combination with fomesafen. Data for both weed species were analyzed by size. Overall, control decreased as size increased. Dicamba, 2,4-D, glufosinate, and combination of those herbicides and mesotrione all resulted in >98% control of 5-10 cm common ragweed. Dicamba, 2,4-D, and glufosinate alone and in combination with fomesafen resulted in >96% control of 10-20 and 20-30 cm common ragweed. Mesotrione provided 53, 35, and 17% control of 5-10, 10-20, and 20-30 cm weeds, respectively. Seed production of 20-30 cm common ragweed was reduced greatest from dicamba, 2,4-D, and glufosinate alone and in combination with fomesafen. Fomesafen significantly increased control and seed production reduction of effective SOAs.Glufosinate alone and combinations of mesotrione, dicamba, 2,4-D, and glufosinate all plus fomesafen provided >90, 80, and 65% control of 5-10, 10-20, and 20-30 cm Palmer amaranth, respectively. Mesotrione alone provided 50, 25, and 22% control of 5-10, 10-20, and 20-30 cm Palmer amaranth, respectively. The addition of fomesafen to effective SOAs increased control across weed sizes but did not significantly affect seed production. Dicamba, glufosinate, fomesafen alone as well as fomesafen in combination with mesotrione, dicamba, 2,4-D, and glufosinate resulted in the greatest decrease in seed production. These studies reinforce the importance of targeting small (<10cm) weeds as well as the effectiveness of auxin herbicides and glufosinate combined with fomesafen on PPO-susceptible Palmer amaranth. Future research will examine the effects of these POST herbicides in programs with effective PRE's to better inform herbicide resistance mitigation management strategies.

Herbicide Potential for Palmer Amaranth (*Amaranthus palmeri*) Control in Sugarbeet, Selectivity of Desmedipham and Phenmedipham. Clint W. Beiermann*[1], Cody F. Creech[1], Amit J. Jhala[2], Stevan Knezevic[3], Robert Harveson[1], Nevin Lawrence[1]; [1]University of Nebraska-Lincoln, Scottsbluff, NE, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]University of Nebraska-Lincoln, Concord, NE (435)

Desmedipham plus phenmedipham was previously labeled for control of pigweeds (*Amaranthus spp.*) in sugarbeet. There are currently no effective POST options to control glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) in sugarbeet. Sugarbeet growers are interested in using desmedipham plus phenmedipham to control escaped Palmer amaranth. In 2019 a greenhouse study was initiated at PHREC located in Scottsbluff, NE to determine the selectivity of desmedipham and phenmedipham between Palmer amaranth and sugarbeet (*Beta vulgaris*). Three populations of Palmer amaranth and four sugarbeet varieties were evaluated. Herbicide treatments consisted of desmedipham plus phenmedipham applied together and each applied individually at an equivalent rate. The standard rate of desmedipham and phenmedipham is 273 g ai ha^{-1} when formulated as a pre-package mixture. In the first run of the experiment rates were: 0.5x, 1x, 2x, and 4x of the standard rate. In the second run 0.25x and 8x rates were added. All herbicide treatments were applied at both the Palmer amaranth and sugarbeet cotyledon stage, and at two true leaf sugarbeet and seven 7 cm high Palmer amaranth. The selectivity indexes for desmedipham, phenmedipham, and desmedipham + phenmedipham were 1.61, 2.47, and 3.05 respectively at the cotyledon stage. At the two true leaf application mortality was not achieved in sugarbeet by the tested rates of desmedipham and phenmedipham, the desmedipham + phenmedipham treatment resulted in a selectivity index of 2.15. Desmedipham and phenmedipham have potential to control Palmer amaranth in sugarbeet if applied at the cotyledon stage, but have limited activity on larger Palmer amaranth.

Comparing Weed Communities of Perennial and Annual Small Grain Cropping Systems.
Eugene P. Law*[1], Matthew P. Spoth[1], Sandra Wayman[1], Christopher J. Pelzer[1], Scott H. Morris[1], Matthew R. Ryan[1], Antonio DiTommaso[2]; [1]Cornell University, Ithaca, NY, [2]Cornell University, Dryden, NY (436)

Perennial small grain crops have the potential to enhance row cropping systems by improving soil health, water quality, and other ecosystem services. Two of these perennial crops, 'Kernza' intermediate wheatgrass (*Thinopyrum intermedium*) and 'ACE-1' perennial cereal rye (*Secale cereale* x *S. strictum*), are reaching commercial viability but require substantial research in many areas of crop management in order to provide growers with tools for successful adoption. Managing weeds in these novel perennial systems is one of these areas that has yet to be thoroughly studied. To develop a baseline understanding of what weed management in perennial grain crops might entail we compared the weed communities in Kernza and ACE-1 stands to those of hard red winter wheat over a three-year period in the Finger Lakes region of New York. The impact of frost interseeding medium red clover (*Trifolium pratense*) with each of the small grain species was also evaluated. The experiment was designed as a split-plot RCBD replicated four times with the three grain species as main treatments and interseeded clover as a split plot treatment. All weed and crop biomass was sampled from two 0.5 m^2 quadrats per plot just prior to grain harvest each year. Weeds were separated by species and all biomass was dried at 60 C before weighing. Total weed biomass and crop biomass and yields were analyzed using mixed effects ANOVA, and weed communities were analyzed with NMDS and PERMANOVA in R. Kernza and ACE-1 exhibited very different responses to weed competition and the clover intercrop, with Kernza being slower to establish but eventually excluding weeds over time while ACE-1 performed well in its first growing season but struggled with competition while regrowing after harvest and was practically excluded by the third year. Weed communities were similar between treatments at the first harvest but differed by both crop species and intercropping treatments in subsequent years. After three years only a few perennial weed species, including *Poa trivialis*, *Phleum pratense*, and *Solidago canadensis*, remained in Kernza plots, especially those that also included red clover, while annual wheat plots contained a wider variety of both annual and perennial species. These observations have informed additional research on cultural and chemical weed management strategies for these two perennial grain crops which will also be briefly discussed.

Herbicide Efficacy on Threespike Goosegrass (*Eleusine tristachya*) in California Orchards.
Drew A. Wolter*[1], Brad Hanson[2]; [1]University of California, Davis, Sacramento, CA, [2]University of California, Davis, Winters, CA (437)

Eleusine tristachya (threespike goosegrass) is related to the more widely distributed *Eleusine indica* (goosegrass). While *E. indica* is a large stature and erect annual, *E. tristachya* is a tufted, low growing, perennial (or semi-perennial) grass of growing concern in California's Central Valley orchard production systems. In 2017, 2018, and 2019, field studies were conducted in a walnut orchard in Chico, CA and an almond orchard in Livingston, CA to evaluate the performance of several pre-emergent (PRE) and post-emergent (POST) herbicide control options. The trial design was a randomized complete block with four replications. Plots in Livingston were 15 ft by 10 ft with one tree per plot, while plots in Chico were 20 ft by 10 ft with one tree per plot. Herbicide treatments were applied with a CO2 pressurized backpack sprayer, calibrated to deliver 30 GPA at 35 PSI, through three TeeJet XR11003 flat fan nozzles. Data collection included visual assessments at monthly intervals for PRE treatments, starting one month after the January application and continued for five months. One treatment included an additional PRE- application in March as part of a sequential herbicide program. POST treatments were applied in May and control assessments were conducted at weekly intervals, starting one week after application, for five weeks. *E. tristachya* control was estimated using a 0 to 100 scale, where 0 means no control and 100 means plants were completely killed. The most efficacious PRE control was obtained through sequential herbicide applications (SHA) of indaziflam followed by pendimethalin, which provided 90% control, five months after the initial treatment. The highest level of POST control was obtained with sethoxydim, clethodim, and fluazifop which all controlled tillered *E. tristachya* greater than 75%, five weeks after treatment (WAT). Glyphosate applied at a common field rate or twice that rate proved to be the least efficacious, with less than 54% control five WAT. The results from this study indicate that a properly timed and applied SHA, along with the use of POST graminicides, provides the greatest control of *E. tristachya,* while glyphosate provides poor management of this species.

Trials and Tribulations with the Integrated Harrington Seed Destructor in Arkansas.
Tom Barber*[1], Thomas R. Butts[1], Jason K. Norsworthy[2]; [1]University of Arkansas System Division of Agriculture, Lonoke, AR, [2]University of Arkansas, Fayetteville, AR (438)

Herbicide resistance continues to increase at alarming levels in Arkansas. Populations of Palmer amaranth that are resistant to 6 herbicide modes of action exist in some areas. In addition, scattered barnyardgrass populations have been found resistant to as many as 5 herbicide modes of action. With the increasing spread of herbicide resistant weeds it is apparent that cultural and mechanical methods are needed in an integrated weed management approach for control of key weed species. The Harrington Seed Destructor was invented by farmer Ray Harrington in Australia. The concept of harvest weed seed control has been adopted by many growers in his region due to the lack of herbicide options for resistant weed species. Through cooperation with Debruin Engineering, a single mill integrated Harrington Seed Destructor was delivered to Newport, Arkansas and installed in the rear of a John Deere 9760 STS combine, equipped with a conventional 30ft draper head, in August 2018. Studies were designed to determine the effectiveness of the integrated Harrington Seed Destructor on Palmer amaranth seed and thus reduction to the soil seedbank.

Initial trials indicate that the design of the single mill Harrington Seed Destructor may not suffice in its current form, for Arkansas soybean harvest. Results from first harvest runs with the destructor in 2018 reveal that weed-free soybean can be harvested at normal speeds with no issues. Unfortunately, any moisture from green plant tissue parts in weedy areas of the field end up in the lower chaff fraction and result in the rapid clogging of the seed destructor mill. However, following a killing frost in November of 2018, soybean heavily infested with Palmer amaranth was successfully harvested at 5 mph, which is further indication that all plant vegetation must be dried or desiccated prior to harvest to prevent clogging and allow for adequate destruction of the lower chaff fraction. From 2018-2019, several modifications to the seed destructor were made. First, a newly designed funnel was installed in attempt to increase the steady flow of the lower chaff fraction into the mill. In addition, modifications of the large chaff separator plate were designed to improve separation of large and small chaff residue preventing stems and larger plant parts from entering the cage mill of the destructor. A harvest aid application of paraquat (0.56 kg aiha^{-1}) plus sodium chlorate (5.6 kg aiha^{-1}) was made to the field in 2019, 15 days prior to harvest for desiccation of any green plant tissue. Results from 2019 indicate that if at least 95% desiccation of green vegetation occurs, the seed destructor does not clog at slower harvest speeds. However, if the amount of weed vegetation moving through the combine increases, or if harvest speed is increased, then the potential for clogging the seed destructor also increases. It has been determined that another funnel design will be necessary for successful continuous movement of the lower chaff fraction into the seed destructor. It is also theorized that the addition of a second mill will reduce clogging and increase harvest speed. Trials will continue with the single mill in 2020, with plans to acquire a larger combine (class 9) and evaluate a 2-mill seed destructor system for comparison.

Initial Impressions of the Seed Terminator™ as a Harvest Weed Seed Control Tool After One Season of Evaluation in Missouri. Kevin W. Bradley*; University of Missouri, Columbia, MO (439)

Impact mills were first discovered and commercialized in Australia primarily to destroy seed of escaped, herbicide-resistant *Lolium* species at the time of wheat harvest. One of the commercially-available devices in Australia is called the Seed Terminator™, which consists of a multi-stage hammer mill integrated into combines that is designed to impact, shear, crush, and/or grind weed seeds and render them non-viable once they exit the combine. In 2019 we were able to obtain a Seed Terminator™ and install it into a Case IH 8250 class 8, field-scale combine and conduct research on the efficacy of this device in four soybean fields located in central Missouri. Our initial results from this work indicate that the majority of waterhemp and other weed seed that enter the Seed Terminator will most likely be rendered non-viable. However, our research also indicates that there is header and thresher loss of weed seed that may not have been considered in some of the previous stationary threshing experiments conducted in controlled environments. Lastly, engine load of the combine was from 8 to 31% greater and fuel consumption was 0.2 to 0.5 gallons/acre greater when the seed terminator was engaged compared to when it was not. In addition to this specific data, our initial impressions after one season of work are that the amount of moisture present in weeds at the time of harvest and/or date of first frost in relation to harvest progress are likely to be important factors that affect the suitability of impact mills for use in U.S. soybean production.

Man vs Machine: Using Drone Aerial Imagery to Accurately Quantify Herbicide Tolerance. Eric N. Johnson, Christian J. Willenborg, Steve Shirtliffe*, Hemma Duddu; University of Saskatchewan, Saskatoon, SK, Canada (440)

The traditional visual rating system is labor-intensive, time-consuming, and prone to human error. Unmanned aerial vehicle (UAV) imagery-based vegetation indices (VI) have potential applications in high-throughput plant phenotyping. The study objective is to determine if UAV imagery provides accurate and consistent estimations of crop injury from herbicide application and its potential as an alternative to visual ratings. Fababean (*Vicia faba* L.) crop tolerance to nine herbicide tank mixtures was evaluated with 2 rates distributed in a randomized complete block design (RCBD) with 4 blocks. The trial was imaged using a multispectral camera with a ground sample distance (GSD) of 1.2?cm, one week after the treatment application. Visual ratings of growth reduction and physiological chlorosis were recorded simultaneously with imaging. The optimized soil-adjusted vegetation index (OSAVI) was calculated from the thresholded orthomosaics. The UAV-based vegetation index (OSAVI) produced more precise results compared to visual ratings for both years. The coefficient of variation (CV) of OSAVI was ~1% when compared to 18-43% for the visual ratings. Furthermore, Tukey's honestly significance difference (HSD) test yielded a more precise mean separation for the UAV-based vegetation index than visual ratings. The significant correlations between OSAVI and the visual ratings from the study suggest that undesirable variability associated with visual assessments can be minimized with the UAV-based approach. UAV-based imagery methods had greater precision than the visual-based ratings for crop herbicide damage. These methods have the potential to replace visual ratings and aid in screening crops for herbicide tolerance.

The Role of Unintelligent Machines in Weed Management. Eric N. Johnson*, Steven J. Shirtliffe; University of Saskatchewan, Saskatoon, SK, Canada (441)

Abstract not available

Integrating Gene Editing and Synthetic Biology to Develop Next-Generation Herbicide Resistant Crops. Lucas Lieber*; BIOHEURIS, St. Louis, MO (442)

Genome editing without the use of DNA vectors has been reported in important crops like maize and wheat to obtain mutant plants that are completely transgene free. Following a similar approach we have used biolistics to deliver pre-assembled Cas–gRNA ribonucleoproteins into soybean and sorghum explants. Genomic DNA samples were obtained two days after bombardment and fragments surrounding the targeted sequences were amplified by PCR and analysed by amplicon deep sequencing. Indels, including insertions and deletions, occurring at the Cas–nucleases cleavage sites were considered as mutations. Mutagenesis frequency was calculated as the percentage of reads containing mutations over the total reads sequenced for each sample. We obtained mutagenesis frequencies comparable to what has been obtained using similar protocols in other species.On the other hand, protein engineering and synthetic biology was used to evolve plant herbicide protein targets to retain their activity even in the presence of these inhibitors. We characterized the level of herbicide resistance of both random and rationally designed variants of plant proteins targeted by different mode of action herbicides.We are now combining gene editing and synthetic biology to engineer non-GMO crops with multiple herbicide resistan

Value of Weed Maps at Harvest in Wheat Cropping Systems of the PNW. Judit Barroso*[1], Carolina San Martin Hernandez[2], John D. McCallum[3], Dan S. Long[3]; [1]Oregon State University, Adams, OR, [2]Oregon State University, Pendleton, OR, [3]USDA-ARS, Adams, OR (443)

Weed maps created late in the growing season are potentially useful in regions where late maturing weeds are problematic and need to be controlled before they produce seeds. The objective of this study was to spatially characterize the population dynamics of predominant weed species using multi-year spatial data, apply this information into quantifying the effect of treated and untreated weed infestations on wheat (*Triticum aestivum*) yield, and evaluate the potential of weed maps for site-specifically post-harvest weed management. Between 2015 and 2018, a 9.2 ha wheat field was gridded into square 7-m cells. In each year, percent cover and abundance of weed species were visually estimated in each cell and site-specific wheat data acquired. While tumble mustard (*Sisymbrium altissimum*) was the most predominant and competitive species, the spatial distribution of this weed and that of other species varied each year. Tumble mustard and prickly lettuce (*Lactuca serriola*) were equally problematic in spring wheat and winter wheat whereas Russian-thistle (*Salsola tragus*) was problematic in spring wheat and downy brome (*Bromus tectorum*) in winter wheat. Spatial patterns in the weed community were subject to rapid change and depended on year, crop, and weed control strategy. Weed maps at harvest have been proved useful for studying weed dynamics, identifying potentially herbicide-resistant weeds, and planning site-specific weed management. Combined with yield information, weed maps at harvest are also useful for explaining crop yield variability that is associated with weed competition and weed control in furtherance of integrated weed management strategies.

Sustaining the Utility of Herbicides in U.S. Agriculture: What Have We Learned and What is the Path Forward? Jason K. Norsworthy*[1], Muthukumar V. Bagavathiannan[2]; [1]University of Arkansas, Fayetteville, AR, [2]Texas A&M University, College Station, TX (477)

Despite strong efforts by weed scientists to mitigate herbicide-resistant weeds, resistance still evolves and spreads in U.S. cropping systems at an alarming rate. Many troublesome weeds in important cropping systems in the U.S. exhibit multiple resistance to five or more herbicide sites of action (SOA). With the rate of resistance evolution far exceeding the commercialization of new herbicide SOA, increased integration of effective tactics is warranted to sustain existing herbicide options. The current best management practices developed and recommended today has primarily been centered on target-site resistance mechanisms, with little consideration to non-target site mechanisms. Some weed populations have been shown to express both target-site and non-target site resistance mechanisms, making confirmation and understanding of the latter more challenging. While "rotate or mix differing effective sites of action" is a common recommendation for mitigating target-site resistance, the implications of this approach on non-target site resistance, specifically enhanced metabolism-based resistance, is not well understood and may at times be counterproductive if herbicides pertaining to differing SOA are metabolized via a similar mechanism. If chemical control options are to remain effective and continue as the foundation of

most weed control programs, there must be greater integration of cultural and mechanical approaches to weed management that reduce the current selection pressure exerted by almost sole reliance on herbicides in many production systems. The chemical industry routinely embraces and even incentivizes strategies involving herbicides such as overlaying residual herbicides and herbicide mixtures, but financial support for non-chemical approaches is lacking at the grower level. It is our belief that chemical companies should also be investing in cover crop seed companies, equipment companies, or other entities that would encourage a true integration of tactics into current cropping systems. Considering that non-target site resistance has strong implications on the utility of herbicides that are yet to be discovered or commercialized, the need for rotation of diverse strategies within and between cropping seasons, with a strong emphasis on prevention of weed seed production and long-term seedbank management, is the only viable and sustainable path forward, and industry, academia, and governmental agencies must collectively work towards achieving this goal.

Presence of Neighbouring Weeds Alters the Response of Maize to Thiamethoxam. Megan House[1], Sasan Amirsadeghi[2], Clarence Swanton*[3], Lewis Lukens[2]; [1]University of Saskatchewan, Saskatoon, SK, Canada, [2]University of Guelph, Guelph, ON, Canada, [3]University of Guelph, Guelph, AZ, Canada (478)

Thiamethoxam (TMX), a neonicotinoid insecticide, in addition to protecting germinating seedlings from herbivorous insects, has non-specific effects on plant growth including increased seedling vigor. Recent studies indicate that environmental stress factors, such as drought and neighboring weeds, can also alter plant responses to TMX. The molecular mechanisms behind both stable and condition-specific responses to TMX likely involve jasmonic acid, JA, and salicylic acid, SA, biosynthesis and response pathways. We investigated the effect of a TMX seed treatment on global gene expression in maize coleoptiles both under normal conditions and under low red to far-red (R/FR) light stress induced by the presence of neighboring weeds. In the absence of weeds, TMX does not affect SA biosynthesis but represses SA response genes involved in (a)biotic stress such as fungal and bacterial diseases. In addition, TMX represses genes encoding enzymes involved in the non-jasmonic acid-forming pathway as well as the jasmonic acid response pathway, thereby compromising resistance to herbivores. In contrast, the presence of weeds reversed these effects. This weed-mediated alteration in the response of maize to TMX may regulate the balance between the JA- and SA-response pathways. These responses appear to be species-specific and conditional with the type and severity of stress. These findings have significant implications for assessing the non-specific effects of seed treatments in major crop plants that may compromise plant resistance to non-target herbivores and pathogens.

Italian Ryegrass (*Lolium perenne* Ssp. *multiflorum*) Timing of Removal Effects on Corn Growth and Yield in Mississippi. Michael T. Wesley Jr.[1], J Connor Ferguson*[1], Jason A. Bond[2], Daniel B. Reynolds[1], Erick J. Larson[1]; [1]Mississippi State University, Mississippi State, MS, [2]Mississippi State University, Stoneville, MS (479)

A field study was conducted to determine the effects of Italian ryegrass (Lolium perenne ssp. multiflorum) removal timing on corn (Zea mays L.) productivity in Mississippi. A study was conducted to understand the effects of Italian ryegrass removal timing on corn production in

Mississippi. Italian ryegrass was removed at different dates relative to corn planting in the winter and spring of 2018 and 2019. Between the earliest removal timing in 2018, which was made 90 days before planting (DBP), and the application made at planting (AP), a yield loss of 3,040 kg ha^{-1} was observed (34 kg ha^{-1} daily loss). A yield loss of 2,454 kg ha^{-1} occurred between the 22 DBP timing and the AP application (112 kg ha^{-1} daily loss). In 2019, a 3,122 kg ha^{-1} yield loss occurred between the earliest removal timing (70 DBP) and the AP timing (45 kg ha^{-1} daily loss). Between the 29 DBP application and the AP treatment, a yield loss of 2,279 kg ha^{-1} was observed (79 kg ha^{-1} daily loss). Data from this study suggest that the optimum time to remove Italian ryegrass is approximately 3 to 4 weeks prior to corn planting. Yields began declining when Italian ryegrass was controlled later than this period. It is anticipated that these results will allow Mississippi growers to maximize profitability by controlling Italian ryegrass at an optimum time prior to corn planting.

Optimizing the Use of Pyroxasulfone for Grass Weed Control in Cool-Season Grasses Grown for Seed. Andrew G. Hulting*, Kyle Roerig, Caio A. Brunharo, Carol Mallory-Smith; Oregon State University, Corvallis, OR (480)

Annual bluegrass (*Poa annua*) and roughstalk bluegrass (*Poa trivialis*), among other grass weed species, invade newly established and established cool season grasses grown for seed in OR causing significant production and economic challenges for grass seed growers. Field experiments were conducted from 2007-2019 to determine the potential for using fall-applied applications of pyroxasulfone and a commercial premix of pyroxasulfone and flumioxazin to control grass weed species and volunteer crop plants in perennial ryegrass and tall fescue grown for seed. A range of application rates and timings of these products were compared to current industry standards including applications of diuron, metolachlor, dimethenamid and flufenacet plus metribuzin. Weed control efficacy, crop injury and crop yield were evaluated each year. Pyroxasulfone applications resulted in excellent annual bluegrass control (greater than 90 %) and were less injurious to both tall fescue and perennial ryegrass than other treatments. Application rates ranging from 50-100 g ai/ha resulted in little crop injury and no yield loss. Applications of the pyroxasulfone and flumioxazin premix at rates of 80-160 g ai/ha provided excellent annual bluegrass control. These studies suggest that these active ingredients provide good weed control as well as adequate crop safety when applied to established perennial ryegrass and tall fescue and are reasonable alternatives to current soil-applied herbicides used in grass seed production systems. Additional trials are ongoing to build needed efficacy and crop safety data sets should industry choose to pursue uses of other products containing pyroxasulfone in grasses grown for seed.

Effect of Cereal Residual Herbicides on Faba Bean Planted the Following Season. Sid A. Darras*, Eric N. Johnson, Christian J. Willenborg; University of Saskatchewan, Saskatoon, SK, Canada (481)

Faba bean (*Vicia faba* L.) is an optimal rotational pulse crop in western Canada because it fixes atmospheric nitrogen and provides for crop diversification of the agroecosystem. However, faba bean is sensitive to the soil residues of some herbicides used in previous years. In this study, seven herbicides were tested (clopyralid, quinclorac, flucarbazone, bromoxynil + pyrasulfotole, dicamba, metsulfuron, and 2,4 D LV 700 Ester) for their potential residual activity on faba bean. The study was carried out at two sites in Saskatchewan, Canada in 2017, 2018, and 2019. The residual herbicides were applied 7 to 10 months before planting faba bean. The results showed that most of the herbicides tested had some potential to cause herbicide injury in faba bean. Significant differences in plant injury symptoms were detected in clopyralid and quinclorac high rate treatments. This was ubiquitous under the certain low soil moisture, low pH, and low soil organic matter content. The residual effects of clopyralid (600 g ai ha^{-1}) caused significant seed yield reduction in faba bean in 2018 by 53% at Kernen site and 54% at Scott site, while quinclorac applied at both the 100 and 200 g ai ha^{-1} rates caused yield reductions in one site-year (Scott site in 2018) by 41% and 80%, respectively.

Intercropping Winter Wheat into Forage Radish (*Raphanus sativus*). Michael L. Flessner*[1], Kara Pittman[1], Mark S. Reiter[2], Eric B. Scruggs[1], Kevin W. Bamber[1]; [1]Virginia Tech, Blacksburg, VA, [2]Virginia Tech, Painter, VA (482)

Forage radish is known to scavenge soil nutrients and alleviate soil compaction. After forage radish winterkills, nutrients are released through decomposition, potentially coinciding with spring wheat growth and associated nutrient demand. Planting wheat into forage radish may realize a nutrient cycling benefit, but must not interfere with wheat yield. Field research was conducted in Blackstone and Painter, VA in 2018-19 to evaluate potential wheat yield loss when intercropped with forage radish. A 6 by 2 factorial structure of forage radish seeding rate and spring fertility (none or 56 kg N ha^{-1} applied mid-February) was used. Forage radish was drilled at 0, 2.24, 4.48, 6.72, 8.96, and 13.4 kg ha^{-1} in late September. Wheat was drilled across the experiment at 134 kg ha^{-1} in late October. Plot sizes were 2.4 by 9.1 m, and treatments were arranged in a randomized complete block with four replications. Thifensulfuron (17.5 g ha^{-1}) + tribenuron (8.8 g ha^{-1}) + 2,4-D (0.6 kg ae ha^{-1}) were applied in mid-February, the same time as spring fertilizer, to kill any over-wintering forage radish and weeds. Stand counts of forage radish and wheat tillers were taken in the fall 6 weeks after wheat planting. Wheat above ground biomass was taken in mid-April. Wheat grain yield and depth to hardpan data were collected in late June. Data were analyzed in JMP Pro using ANOVA followed by regression analysis. Fall stand counts varied by location, but wheat tillers decreased as forage radish plants increased at both locations. In Blackstone, the relationship between wheat tillers per row m (y) and forage radish per row m (x) was defined as $y = 60.6 - 1.97x$, and in Painter, $y = 61.5 - 0.5x$. Spring wheat biomass did not differ as forage radish increased; only spring-applied fertility mattered and resulted in increased wheat biomass over no fertilizer. Wheat grain yield data were only collected in Painter; there was not a significant impact of forage radish per row m on grain yield. Spring applied fertilizer did increase grain yield, which was 910 kg ha^{-1} without fertility and 1610 kg ha^{-1} with fertility. Despite a decrease in wheat tillers in the fall, spring biomass and grain yield were not influenced by forage radish density, indicating that forage radish can be intercropped with wheat. That being the case, improvements in soil quality or N dynamics may be realized as a benefit. Other data collected included soil compaction, wheat and forage radish tissue samples, and soil samples at varying depths, which will be analyzed as a part of future research. Current data indicated that forage radish intercropping treatments did not influence depth to hardpan, which varied by location. In conclusion, forage radish can be intercropped with wheat without a yield loss. Future research should continue to examine wheat yield loss in additional site-years. Additionally, research should examine N cycling via ^{15}N-labeled fertilizer.

Helping Glufosinate Work in the West: Adjuvants, Rates, and Timings. Andrew R. Kniss*; University of Wyoming, Laramie, WY (483)

Previous research has shown that glufosinate provides variable weed control in the Western US, in part, due to low relative humidity near the time of application. Field studies were conducted under irrigated and dryland locations near Lingle, Wyoming in 2019 to evaluate adjuvants and glufosinate rates to improve weed control. Glufosinate was applied once at rates of 0.45, 0.59, 0.74, and 0.84 kg ha^{-1}. Glufosinate was applied sequentially at rates of 0.45 followed by (fb) 0.45 kg ha^{-1}, 0.59 fb 0.45 kg ha^{-1}, and 0.59 fb 0.59 kg ha^{-1}. Adjuvant treatments included glycerol as a humectant, an acidifying agent, a high-surfactant oil concentrate, and non-ionic surfactant. All treatments included ammonium sulfate. Glyphosate treatments (applied at 0.75 or 1.12 kg ha^{-1}) were included as comparison treatments. At the dryland location, all glufosinate treatments provided better control of kochia compared to glyphosate, and sequential applications 7 days apart provided the greatest kochia control. At the irrigated site, glyphosate treatments controlled common lambsquarters better than all single glufosinate treatment regardless of adjuvant or rate. Sequential glufosinate applications that had 0.59 kg ha^{-1} in the first application provided better common lambsuqarters control than either rate of glyphosate.

Preplant Burndown Weed Control with Elevore® Herbicide with Arylex™ Active. Joe Armstrong*[1], Kristin Rosenbaum[2], David Saunders[3]; [1]Corteva Agriscience, Indianapolis, IN, [2]Corteva Agriscience, Coffey, MO, [3]Corteva Agriscience, Dallas Center, IA (484)

Elevore® is a herbicide developed by Corteva Agriscience for the U.S. pre-plant herbicide market segment for control of horseweed (*Conyza canadensis* (L.) Cronq) and other problematic broadleaf weeds. It contains Arylex™ active (halauxifen-methyl), a novel synthetic auxin (WSSA group 4) herbicide from the "arylpicolinate" chemical class. Elevore is an SC formulation with a use rate of 1.0 fl oz product/acre (5 g ae/ha) and is labeled for use prior to soybean, corn, and cotton planting. The Elevore label allows for pre-plant applications 14 days prior to planting of soybean and corn. Field research was conducted from 2015 to 2019 at over 100 locations across the U.S. to determine the efficacy of Elevore applied in the fall and spring to horseweed, including glyphosate-resistant biotypes, and other common weeds prior to planting corn and soybean. Elevore was compared to competitive standards when applied with glyphosate and in tank mixes with glyphosate + 2,4-D low volatile ester (LVE) herbicide. Applied at 5 g ae/ha in combination with glyphosate at 1120 g ae/ha, Elevore provided 89% and 99% efficacy on horseweed and henbit (*Lamium amplexicaule* L.), respectively, and performed similar to or better than glyphosate at 1120 g ae/ha, glufosinate at 542 g ae/ha, dicamba + glyphosate at 280 + 1120 g ae/ha, saflufenacil + glyphosate at 37.5 g ai/ha + 1120 g ae/ha, and paraquat at 420 g ai/ha. Elevore provides growers with an alternative mode of action for many difficult to control, pre-plant burndown broadleaf weeds. ®™Trademarks of Dow AgroSciences, DuPont, or Pioneer and their affiliated companies or respective owners

Introduction and Overview of MON 301107: A New Glyphosate Formulation. Christopher M. Mayo*[1], Ross A. Recker[2], David J. Mayonado[3], Neha Rana[4]; [1]Bayer, Gardner, KS, [2]Bayer, Smithton, IL, [3]Bayer, Hebron, MD, [4]Bayer Crop Science, St Louis, MO (485)

MON 301107 is a new glyphosate formulation. Field trials conducted in 2017 and 2018 in 54 locations evaluated MON 301107 for postemergence weed control compared to commercial standards. The experimental design was a split-plot arrangement with 3-4 replications. Whole-plots consisted of different glyphosate rates and the sub-plots were various glyphosate formulations. Results from 2017-18 trials, 14 days after treatment, indicated MON 301107 at 1120 g a.e. ha^{-1} provided broadleaf control and grass control that was not statistically different than commercial standards at 1120 g a.e. ha^{-1}. Additional field trials conducted in 2019 evaluated crop safety of MON 301107 compared to Roundup PowerMAX® herbicide when used postemergence on multiple crops. The experimental design was a split-plot arrangement with 3-4 replications. Whole-plots consisted of different herbicide treatments and the sub-plots had either MON 301107 or Roundup PowerMAX as the glyphosate formulation utilized in the herbicide treatment. Glyphosate formulation was not a significant treatment factor for any of the percent injury evaluations for field corn hybrids with Roundup Ready® 2 Technology, soybean with Roundup Ready 2 Yield® Technology, cotton with Roundup Ready® Flex Technology Roundup Ready® Alfalfa, or Roundup Ready® Sugarbeet. These results demonstrate MON 301107 can provide non-selective foliar control of both grass and broadleaf weeds and has a comparable crop safety profile to Roundup PowerMAX.

The Bicyclopyrone Weed Control Advantage in a New Premix Product Concept for Corn. Ryan D. Lins*[1], Tom H. Beckett[2], Scott E. Cully[3], Gordon D. Vail[2], Dane L. Bowers[2]; [1]Syngenta, Rochester, MN, [2]Syngenta, Greensboro, NC, [3]Syngenta, Marion, IL (486)

Acuron® GT is a new herbicide coming soon from Syngenta for weed control in glyphosate tolerant field corn. Acuron GT will contain S-metolachlor, mesotrione, bicyclopyrone and glyphosate for postemergence application with knockdown and residual control of grasses and broadleaves. In 2019, field trials were conducted to evaluate Acuron GT for weed control and crop tolerance. Results show that Acuron GT effectively controls many difficult weeds and provides improved residual control and consistency compared to other commercial standards. Acuron GT is not registered for sale or use in the US and is not being offered for sale.

Triazine Benefits in Corn and Sorghum. Carroll Moseley*[1], David Bridges[2], Patricia D. Laird[3]; [1]Syngenta, High Point, NC, [2]Abraham Baldwin Agricultural College, Tifton, GA, [3]Syngenta Crop Protection, Greensboro, NC (487)

An analysis was done to assess the benefits of triazine herbicides when used in corn (atrazine and simazine) and grain sorghum (atrazine) using data from the 2016-2018 growing seasons. The objective was to estimate changes in weed control costs and crop yields if atrazine and simazine were no longer available for US corn and grain sorghum growers. The process and techniques were like those used in previous analyses by Bridges, et al. (1994, 1998, 2008, 2011, and 2016). Herbicide efficacy, costs, and weed populations were evaluated and modeled by USDA Farm Resource Regions. Triazine product base acres were replaced with existing herbicides that had a 2% or greater share of corn or sorghum acreage, with the exception of glyphosate. Glyphosate was held at current use. Triazine herbicides were valued at $3.1B and $189M for corn and sorghum producers, respectively.

Dimetric Charged: A New Option for Burndown and Residual Weed Control. Ryan J. Edwards*[1], Gregory K. Dahl[2]; [1]WinField United, River Falls, WI, [2]WinField United, Eagan, MN (488)

Dimetric® Charged, a combination herbicide containing a Group 5 (metribuzin) and a Group 14 (flumioxazin), is a new option for burndown and residual weed control. Field trials conducted in 2018 and 2019 show an increased knockdown and residual control of tough to control weed like Palmer amaranth (*Amaranthus palmeri*), horseweed (*Conyza canadensis*), common waterhemp (*Amaranthus tuberculatus*) and others. When combined with other POST applied herbicides and high surfactant oil concentrate (HSOC) adjuvants, Dimetric® charged provides longer lasting control.

Impact of Pre-Harvest Glyphosate on Oat (*Avena sativa*). Christian J. Willenborg*[1], Eric N. Johnson[1], Nancy Ames[2]; [1]University of Saskatchewan, Saskatoon, SK, Canada, [2]Agriculture and Agri-Food Canada, Winnpeg, MB, Canada (489)

Applying harvest aid herbicides, such as glyphosate, can dry down crops evenly and quickly, and can help control late-emerging weeds. However, improper application timing may reduce yield and quality, and leave unacceptable herbicide residues in seed, which can cause commercial issues when marketing these crops. Furthermore, increasing public scrutiny towards products such as glyphosate can have impacts on consumer markets. Little published evidence exists regarding pre-harvest glyphosate applications in several crops, yet this information is critical to the industry and to consumer confidence. We have conducted over the past five years studies using pre-harvest glyphosate in oat production. These trials examined the timing of glyphosate application, and the impact of agronomic management practices on crop yield, quality, and glyphosate seed residues. Our data indicate that application of glyphosate at seed moisture contents below 30% results in no reductions in crop yield or quality, and significantly limits seed residue content. In fact, various quality and yield parameters were actually improved by pre-harvest application of glyphosate compared with a swathing treatment. Applications of glyphosate at seed moisture contents in excess of 30% seed moisture did result in undesirable residues, as well as substantial reductions in crop yield. Based on our findings, there appears to be limited potential for glyphosate seed residues to exceed North American MRLs for if applications are made at the 30% seed moisture content recommended by the label.

Future of Academic Weed Science from Hemp to Students to Cancer. David D. Baltensperger*; Texas A&M University, College Ststion, TX (490)

This is a philosophical discussion of the future of weed science in academia. The strengths, weaknesses, opportunities and threats for advancing the discipline in the United States based on discussions with key leadership around the country produced several recurring themes emerged in all categories. Strengths include strong partnerships with commodity groups and industry to enhance weed control knowledge and strategies. Most frequently identified weakness was perception of limited capacity to develop unbiased information. Key opportunities include developing and training a workforce for the future through public - private partnerships and investments by USDA-NIFA. Developing partnerships to invest in weed control strategies for alternative crops. Encouraging federal investment in health related issues with pesticides as an unbiased source of information. Encourage federal investment in new technology including artificial intelligence and drone technology. Threats include conflict of interest law suits and failure to communicate with judicial system, but the most frequently raised threat was the failure to identify strategies to address the perception of societal risks from the use of pesticides.

Weed Management in Cotton as Influenced by Cover Crop and Herbicide Program. Pratap Devkota*, Ruby Tiwari, Prasanna Kharel, Michael J. Mulvaney; University of Florida, Jay, FL (491)

In addition to improving crop soil moisture, crop health and crop performance, cover crop benefit by contributing on weed suppression. Field research was conducted to evaluate weed suppression response from wheat, oat, rye, carinata (*Brassica* spp.), and no cover crops, and to integrate them with herbicide programs in a strip-tilled XtendFlex cotton production system. Herbicide programs consisted of PRE applied fomesafen, fluridone, or pyroxasulfone then fb POST applied dicamba for sicklepod and tropical spiderwort control. There was no effect of cover crop for sicklepod or tropical spiderwort control at 4 WAT. Sicklepod control was = 5% with PRE-applied fluridone compared to pyroxasulfone or fomesafen at 4 WAT; however no differences were observed for tropical spiderwort control. At 4 wk after dicamba application, there was no effect of cover crop on sicklepod control; however, tropical spiderwort control was = 45% with rye compared to wheat. A herbicide program consisting of PRE applied fluridone provided higher control of sicklepod and tropical spiderwort compared to the fomesafen program. Cotton injury was minimal (= 3%) from PRE applied herbicides at 4 WAT; however, injury was greater with carinata compared to rye cover crop at 4 wk after dicamba application. Cotton height was 92 cm after rye compared to 78 cm after carinata at 6 wk after dicamba application. Similarly, cotton height was 13 cm taller with fluridone compared to reflex, pyroxasulfone, or no herbicide treatment. Seed cotton yield was significantly higher with PRE applied fluridone herbicide (1,772 kg ha^{-1}) compared to fomesafen, pyroxasulfone, or no herbicide treatment (= 1,291 kg ha^{-1}). This research illustrates that combination of a rye cover crop with PRE-applied fluridone has potential for sicklepod and spiderwort control in Xtendflex cotton production systems.

Florpyrauxifen-benzyl Sensitivity in *Gossypium hirsutum*, as Influenced by Application Placement. Ryan C. Doherty*[1], Tom Barber[2], Leah M. Collie[3], Zachary T. Hill[4]; [1]University of Arkansas Division of Agriculture Research & Extension, Monticello, AR, [2]University of Arkansas System Division of Agriculture, Lonoke, AR, [3]University of Arkansas System Division of Agriculture, Beebe, AR, [4]University of Arkansas Cooperative Extension Service, Monticello, AR (492)

Cotton (*Gossypium hirsutum*) herbicide systems that contain multiple modes of action and are applied timely are essential in controlling Palmer amaranth (*Amaranthus palmeri*) resistant to multiple herbicides. Arkansas cotton growers are in need of new and improved methods and chemistry, to manage this troublesome weed. Two post-direct trials were established in 2018, and 2019, additionally a foliar trial was also established in 2019, to evaluate crop response following florpyrauxifen-benzyl applications in cotton. In 2018 and 2019 trials were established at Marianna, AR in a Loring silt loam soil and at Tillar, AR in a Herbert silt loam soil. In 2018, post-direct trials were established in Enlist cotton at both locations. In 2019, post-direct trials were established in

PHY 350 W3FE at Tillar and DP 1646 B2XF at Marianna, while foliar trials at both locations were established in PHY 350 W3FE .The trials were arranged in a randomized complete block design with four replications. All treatments received fluometuron at 1052 g ai ha^{-1} plus fluridone at 215 g ai ha^{-1} preemerge followed by glufosinate at 469 g ai ha^{-1} plus metolachlor at 1390 g ai ha^{-1} at 3-4 leaf cotton. Post-directed herbicides evaluated included diuron at 1121 g ai ha^{-1}, florpyrauxifen-benzyl at 9.08, 14.6, and 29.14 g ai ha^{-1}, and glyphosate at 1255 g ai ha^{-1}. Foliar herbicides evaluated included florpyrauxifen-benzyl at 7.3, 11, 14.6, and 29.14 g ai ha^{-1}plus glyphosate at 1255 g ai ha^{-1}. In 2018 post-direct applications were applied to 10 node cotton. In 2019 post-direct and foliar applications of florpyrauxifen-benzyl were applied to 8 or 10 node cotton. Visual crop injury, in the form of epinasty, was recorded 20 days after post-direct applications and 8 and 14 days after foliar applications. Cotton was harvested and seed cotton yield was recorded.In 2018, No visual crop injury was noted with florpyrauxifen-benzyl at 9.08, 14.6 g ai ha^{-1} or any tank-mix, at either Tillar or Marianna. Cotton yield was not impacted negatively by any post-direct treatment, at either Tillar or Marianna. All treatments provided equal cotton yields at the respective location.In 2019, post-direct crop injury at Marianna increased as the florpyrauxifen-benzyl rate increased. Visual injury ranged from 2.5% with florpyrauxifen-benzyl at 9.08 g ai ha^{-1} to 11.3% with 29.2 g ai ha^{-1}. No visual injury was noted, in any florpyrauxifen-benzyl treatment, at Tillar. Cotton yield was reduced by 9 of the 10 florpyrauxifen-benzyl treatments at Marianna, while yield was equal or greater than the weed-free check with all treatments at Tillar. The highest yield reduction was noted when florpyrauxifen-benzyl was applied at 29.14 g ai ha^{-1} to 8 node Xtend cotton. When florpyrauxifen-benzyl was applied foliar to 8 node PHY 350 W3FE cotton, at a rate of 7.3, 11, 14.6, or 29.14 g ai ha^{-1}plus glyphosate at 1255 g ai ha^{-1}, epinasty ranged from 54-83% at Tillar and 85-88% at Marianna 8 days after the application. At 14 days after the 10 node application, epinasty was 10-74% at Tillar and 31-55% at Marianna. In 2019, Marianna Xtend cotton yield was reduced by 9 of the 10 florpyrauxifen-benzyl post-direct treatments, while when applied foliar to Enlist cotton all treatments were equal to the weed-free check. Tillar cotton yield was equal to or greater than the weed-free check with all post-direct and foliar treatments, with the exception of 29.2 g ai ha^{-1} of florpyrauxifen-benzyl applied foliar to 10 node cotton.

Kochia (Bassia scoparia) Control in Enlist™ Cotton (*Gossypium hirsutum*) Following Different Preplant Herbicide Options in the Texas High Plains. Ubaldo Torres*[1], Peter A. Dotray[2], Kyle R. Russell[1], Michael Lovelace[3]; [1]Texas Tech University, Lubbock, TX, [2]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX, [3]Corteva Agriscience, Lubbock, TX (493)

Kochia (*Bassia scoparia L.)* is an annual weed introduced from Eurasia and is commonly found throughout the western and northern United States. Kochia is well-adapted to the arid to semi-arid region of the Texas High Plains, making it a common weed if not properly managed early in the growing season. Herbicide resistant kochia has been reported in Texas, which adds to the complexity of effective weed management systems. The objective of this study was to evaluate kochia control following preplant herbicide treatments in an Enlist™cotton system in the Texas High Plains. Studies were conducted in 2018 and 2019 at the Texas A&M AgriLife Research and Extension Center in Lubbock. Eight treatments (flumioxazin (Valor® SX) at 0.077 kg ai/ha plus 2,4-D amine at 1.2 kg ai/ha; rimsulfuron at 0.018 kg ai/ha plus thifensulfuron at 0.018 kg ai/ha

(LeadOff®) plus 2,4-D amine; fluroxypyr (Starane® Ultra) at 0.17 kg ai/ha plus 2,4-D amine; flumioxazin plus glyphosate (Roundup PowerMAX®) at 1.7 kg ae/ha; rimsulfuron and thifensulfuron plus glyphosate; fluroxypr plus glyphosate; dicamba (FeXapan™) at 0.61 kg ae/ha plus glyphosate and rimsulfuron and thifensulfuron plus thifensulfuron, flumioxazin, and tribenuron (Afforia®) at 0.89 kg ai/ha plus glyphosate) were applied with a CO_2- pressurized backpack sprayer 45, 30 and 15 days before planting (DBP). PhytoGen 330 W3FE was planted in both years followed by fluometuron at-planting, in-season applications of 2,4-D choline and glyphosate (Enlist Duo®), tillage, and diuron postemergence-directed. In 2018, kochia was controlled at least 92% at planting by several preplant treatments including flumioxazin plus 2,4-D, thifensulfuron and rimsulfuron plus 2,4-D, fluroxypyr plus 2,4-D, fluroxypyr plus glyphosate, and dicamba plus glyphosate when applied 45 DBP. There was more variability in kochia control in 2018 and only dicamba plus glyphosate controlled this weed greater than 90% at planting. In 2019, kochia was controlled at least 90% following fluroxypyr plus 2,4-D, fluroxypyr plus glyphosate, and dicamba plus glyphosate when applied 45 DBP. Treatments applied 30 DBP in 2019 had greater efficacy than treatments applied 45 or 15 DBP. In 2018, there was no difference between treatments applied at 45 and 30 DBP and both timings had greater efficacy than treatments applied at 15 DBP. Treatments containing glyphosate instead of 2,4-D applied 15 DBP provided better kochia control in 2019. Dicamba plus glyphosate injured Enlist™ cotton in both years. No other treatment caused visible cotton injury. Cotton yield following all treatments was greater than the non-treated control, but no differences were observed among treatments.

Use of Isoxaflutole as an Alternative Herbicide Site of Action in Cotton. Rodger B. Farr*[1], Jason K. Norsworthy[1], Tom Barber[2], Grant L. Priess[1], Mason C. Castner[1]; [1]University of Arkansas, Fayetteville, AR, [2]University of Arkansas System Division of Agriculture, Lonoke, AR (494)

The evolution of herbicide resistance by troublesome weeds such as Palmer amaranth (*Amaranthus palmeri* S. Watson) has limited the number of weed control options in cotton. As of current, there are seven sites of action to which Palmer amaranth has developed resistance, prompting the search for more effective herbicide options in cotton (*Gossypium hirsutum* L.). 4-Hydroxyphenylpyruvate dioxygenase herbicides such as isoxaflutole (IFT) have been shown to be effective at controlling small-seeded broadleaf weeds such as Palmer amaranth in corn (*Zea mays* L.) but is currently not available in cotton. The recent development of IFT-resistant cotton by BASF will allow for the integration of a new effective site of action in cotton. To determine the utility of the addition of IFT into cotton production systems a study was conducted in the fall of 2019 in Marianna, AR evaluating nine different herbicide programs. The study was conducted as two experiments, one evaluating crop tolerance and the other evaluating weed control. Both studies were one-factor, randomized complete block design with the treatments consisting of different programs utilizing different preemergence, early-postemergence, and mid-postemergence programs containing different typical cotton herbicides with and without the addition of IFT. Visual estimates of weed control were taken every 7 days after each application until 35 days after layby. The results from the crop tolerance experiment show that all treatments caused no more than 5% injury to cotton and no significant effect on yield or stand. The results from the weed control experiment showed that the use of IFT in cotton herbicide programs provided improved control of Palmer amaranth as a preemergence or early-postemergence option. Average Palmer amaranth control 21 days after the early-postemergence application was 94% for treatments containing IFT compared to 79% for those that did not. The study also found that the use of residual herbicides with each postemergence application and the use of layby applications provided lasting weed control through the end of the season.

Evaluating Tank Mix Partners with Isoxaflutole Across the Cotton Belt. Delaney C. Foster*[1], Peter A. Dotray[2], Seth A. Byrd[3], A Stanley Culpepper[4], Darrin M. Dodds[5], Steven D. Hall[6], Bradley J. Norris[5], Reagan L. Noland[7], Scott A. Nolte[8], Mason T. House[9], Jason K. Norsworthy[10], Rodger B. Farr[10], Larry Steckel[11], Corey Thompson[12]; [1]Texas Tech University, Lubbock, TX, [2]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX, [3]Oklahoma State University, Stillwater, OK, [4]University of Georgia, Tifton, GA, [5]Mississippi State University, Mississippi State, MS, [6]Mississippi State University, Starkville, MS, [7]Texas A&M Agrilife Extension Service, San Angelo, TX, [8]Texas A&M AgriLife Extension, College Station, TX, [9]Texas A&M University, College Station, TX, [10]University of Arkansas, Fayetteville, AR, [11]University of Tennessee, Jackson, TN, [12]BASF, Abernathy, TX (495)

The increase in number of herbicide resistant weeds threatens Texas cotton (*Gossypium hirsutum L.*) production and profitability and forcing producers to use multiple herbicide modes of action to manage weeds. The use of auxinic herbicides has helped control troublesome weeds; however, these technologies have elevated risk due to off-target movement. *P*-hydroxyphenylpyruvate dioxygenase (HPPD) inhibitors are a relatively new class of herbicide chemistry although first available for use in the 1980's. While current varieties do not tolerate HPPD inhibitors, BASF Corporation has developed HPPD-tolerant cotton that will allow growers to use isoxaflutole in future weed management programs. Utilizing multiple modes of action that include the use of soil residual herbicides will increase weed management options and help in the stewardship of old and new technologies to slow the development and spread of herbicide resistant weeds. In 2019, a research project was developed in collaboration with a number of universities and BASF Corporation to examine weed control following isoxaflutole applied preemergence alone and when used with a number of tank mix partners. Treatments included isoxaflutole at 0.11 kg ai/ha applied alone and tank mixed with half and full rates of the following cotton herbicides: fluometuron at 0.56 and 1.12 kg ai/ha, prometryn at 0.67 and 1.35 kg ai/ha, diuron at 0.56 and 1.12 kg ai/ha, fluridone at 0.08 and 0.17 kg ai/ha, fomesafen at 0.14 and 0.28 kg ai/ha, pendimethalin at 0.56 and 1.12 kg ai/ha, *S*-metolachlor at 0.7 and 1.4 kg ai/ha, acetochlor at 0.63 and 1.26 kg ai/ha, and pyrithiobac at 0.029 and 0.058 kg ai/ha. There were nine total locations conducted in Arkansas, Georgia, Mississippi, Oklahoma, Tennessee, and Texas. Several weed species were examined but the target weed was Palmer amaranth (*Amaranthus palmeri S. Watson*). Soil residual weed control was evaluated to 56 days after application. When tank mixed with isoxaflutole, fluridone improved residual Palmer amaranth control at five of six locations; however, fluridone is an Herbicide Resistance Action Committee Group F1 herbicide and shares the same mode of action as isoxaflutole but binds to a different enzyme (phytoene desaturase). The addition of fomesafen improved Palmer amaranth control at all locations except College Station, TX. Regardless of location or herbicide mixture, Palmer amaranth control improved when isoxaflutole was applied in tank mix rather than applied alone. Other key weed species evaluated were large crabgrass and morningglory species. In Ideal, GA the addition of diuron, fluridone, fomesafen, pendimethalin, prometryn, and *S*-metolachlor to isoxaflutole increased large crabgrass control when compared to isoxaflutole applied alone. At Mariaana, AR and Bixby, OK, isoxaflutole alone controlled large crabgrass as well as other tank mixtures. At both locations where morningglory species were present (Bixby, OK and College Station, TX), isoxaflutole applied alone controlled morningglory as well as isoxaflutole applied in tank mixtures. These results suggest that isoxaflutole applied preemergence alone or in tank mixture is efficacious on a number of weed species in cotton.

Safety of Pre- and Early-post Herbicides to Hemp for Seed Production. Angela R. Post*; North Carolina State University, Raleigh, NC (496)

There are no herbicides labeled for use in hemp in the United States even though a reported 350,000+ acres of hemp was planted in the US in 2019. The US Environmental Protection Agency is evaluating crop protection chemicals for registration in hemp. In 2019, ten products received registrations, none of which were herbicides. In 2018, The IR-4 Project approved testing in hemp for several herbicides as preemergence and early-postemergence applications. In 2018 and 2019 *Cannabis sativa* 'CFX2' was planted at the Piedmont Research Station in Salisbury NC. Two experiments were planted in each year, one for preemergence product testing and one for early-postemergence herbicide testing. The experiments were randomized complete block designs with four replications. Fields were conventionally tilled and following full-season soybeans. Plots were seeded at 525,000 live seed/A and 50 pounds of N, P and K were applied at planting. Fifty additional pounds of N per acre were applied 4 weeks after planting. Preemergence applications were made on the day of planting or prior to crop emergence. Early post-emergence applications were made over the top of emerged hemp as a broadcast foliar applications when hemp was approximately 8” tall. Preemergence trials included clomazone (10.7 and 21.4 oz/A, sulfentrazone (4.5 and 9 oz/A), flumioxazin (6 and 12 oz/A), and pyroxasulfone (1.5 and 3 oz/A) and s-metolachlor (16, 21 and 27 oz/A). Early post-emergence trials included bromoxynil (8 and 16 oz/A), clethodim 16 and 32 oz/A), and pyroxasulfone (1.5 and 3 oz/A). Both trials included a weedy control and a weed-free control. All applications were made with a 4-nozzle boom using 11002TT tips at 20GPA. Weeds emerged at this location at the time of early post applications included multiple pigweed species (*Amaranthus* sp.) and large crabgrass (*Digitaria sangiunalis*). Data collection included percent visual weed control by species and percent crop injury 1, 10, 21, 28, 35, and 42 days after treatment. We harvested plots with a Wintersteiger Delta small plot combine and recorded as grams of seed per plot. Per acre yield was calculated based on 10% standard seed moisture and reported in pounds per plot and standard test weight of hemp at 44 pounds per bushel. Early-postemergence: With early-postemergence applications, bromoxynil at the 16 oz/A rate and pyroxasulfone at the 3 oz/A rate injured hemp at all rating dates. At the 2X rate Bromoxynil injury averaged 28.8% by 10 days after treatment (DAT) and hemp did not recover throughout the season. Symptoms included leaf burning and stand loss. Leaf burning symptoms improved, but many small seedlings died. At the 3 oz/A rate pyroxasulfone injury averaged 18.8% by 10 DAT and improved slightly to an average of only 16.3% by 28 DAT. Symptoms included: whole plant necrosis and stand loss. Both bromoxynil and pyroxasulfone were safe to *C. sativa* at the 1X rates and provided excellent weed control at 97.5% and 90%, respectively for pigweed species. Clethodim was 100% safe at both 1X and 2X rates and controlled large crabgrass 100% at both rates. In this case, no herbicide treatment significantly affected seed yield compared to the weed-free control. Bromoxynil, pyroxasulfone and clethodim are all viable products for use as early postemergent products to be sprayed over the top of hemp as a broadcast application shortly after crop emergence. Injury was not noted for the 1X rate of these products. The 2X rate of bromoxynil and pyroxasulfone caused commercially unacceptable injury including leaf burning and stand loss. Preemergence: Ten days after treatment (DAT) clomazone at both rates caused bleaching of the crop and weeds as well as hemp stand reductions and stunting. Flumioxazin at both rates, and s-metolachlor at high rates caused visual reductions in stand compared to the weedy-free control. By 21 DAT, visual symptomology including tissue bleaching and leaf curling were no longer evident in any plots. Pyroxasulfone at both rates caused stunting and the two highest rates of s-metolachlor continued to exhibit crop stunting.By 35 DAT hemp had recovered from any mild herbicide injury <30%. Products that injured hemp >50% remained thin; even though weed control was acceptable in these plots, canopy did not close in many cases. Overall, the low rates of s-metolachlor, sulfentrazone and pyroxasulfone may be viable for options for preemergence application to hemp. These materials should be tested across several soil types and other varieties to ensure crop safety across different genetics and soils with differing properties. The IR-4 Project funded this work under P12340.

Challenges and Opportunities for Weed Control in Popcorn. Ethann R. Barnes*[1], Stevan Knezevic[2], Nevin Lawrence[3], Amit J. Jhala[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Concord, NE, [3]University of Nebraska-Lincoln, Scottsbluff, NE (497)

Popcorn is an important field crop to many Midwestern United States producers. Weed control in popcorn is challenging with limited herbicide options and popcorn's perceived sensitivity to herbicides. Herbicides that are labeled in popcorn are often only conditionally labeled with reduce rates, warnings, or limited popcorn types. While there is considerable research on field corn and sweet corn sensitivity to herbicides, there is a lack of information on popcorn sensitivity to herbicides. Three field experiments were conducted from 2017 to 2019 to: (1) determine the critical time for weed removal (CTWR) in popcorn with and without a premix of atrazine and *S*-metolachlor applied PRE; (2) evaluate herbicides labeled for yellow popcorn in commercially available popcorn hybrids for weed control and crop response in Nebraska; (3) evaluate the efficacy and crop safety of labeled POST herbicides for controlling velvetleaf that survived S-metolachlor/atrazine applied PRE and determine effect of velvetleaf height on POST herbicide efficacy, popcorn injury, and yield. Field experiments were conducted at the University of Nebraska?Lincoln, South Central Agricultural Laboratory near Clay Center, NE. The CTWR determined in experiment 1 ranged from the V4 to V5 popcorn growth stage in absence of PRE herbicide. With atrazine/*S*-metolachlor applied PRE, the CTWR was delayed until V10 to V15. In experiment 2, slight hybrid differences in herbicide sensitivity were detected; however, the differences were not linked to popcorn color. Based on contrast analysis, herbicide applications in experiment 3 with fluthiacet-methyl (98%) or dicamba (95-96%) provided similar control 28 DAT compared to 87-90% control without them regardless of velvetleaf height in 2018. All velvetleaf POST herbicides tested in this study provided > 98% control of velvetleaf 28 DAT in 2019. Results from this research conclude (1) weeds must be controlled before the V4 popcorn growth stage when no PRE herbicide is applied to avoid yield loss and PRE herbicide, such as atrazine/*S*-

metolachlor in this study, can delay the CTWR until the V10 growth stage; (2) All herbicide programs labeled in yellow popcorn achieved excellent crop safety in yellow and white popcorn hybrids and resulted in broadleaf weed control; and (3) POST herbicides are available for control of 12 to 30 cm tall velvetleaf in popcorn production fields. This research provides critical information for popcorn producers previously only available in field and sweet corn.

Utility of Two New Premix Concepts Containing Rinskor Active for Improved Efficacy and Weed Spectrum in MidSouth Rice Production. Drew Ellis*[1], Larry C. Walton[2], Hunter Perry[3], Chris J. Meyer[3], Jeff Ellis[4], Mauricio Morell[5]; [1]Corteva Agriscience, Arlington, TN, [2]Corteva, Tupelo, MS, [3]Corteva agriscience, Leland, MS, [4]Dow AgroSciences, Sterlington, LA, [5]Corteva Agriscience, Indianapolis, IN (498)

Planning a rice weed control program is unique in that many times multiple weed species infest a field and due to the chemistry available growers commonly tankmix different herbicide actives to effectively control all weed species. A goal of developing a premix herbicide to control as broad of a range of grass, broadleaf, and sedge weeds is a major focus for agrochemical companies. The launch of Rinskor® active (florpyrauxifen-benzyl) in Loyant® herbicide in 2018 brought about a broad spectrum of weed control to rice. Now there is an opportunity to combine Rinskor® active with penoxsulam (GF-3565 herbicide) for improved control of certain broadleaf weeds, add residual, and multiple modes of action for resistance management. Additionally, adding Rinskor® active with cyhalofop (GF-3479 herbicide) would improve overall grass weed spectrum and provide two effective modes of action on grasses specially to control barnyardgrass that is known to be hard to control. Various field trials were conducted across Arkansas, Louisiana, and Mississippi from 2015 through 2018 to demonstrate the key characteristics stated before. In these trials GF-3565 was applied at a rate of 65 g a.i. ha^{-1} with methylated seed oil product at 0.59 L ha^{-1}. Other trials in the same time period and locations focused primarily on key grass weeds like barnyardgrass, broadleaf signalgrass, and sprangletop spp. with GF-3479 applied at a rate of 344 g a.i. ha^{-1} with methylated seed oil product at 0.59 L ha^{-1}. Additionally, comparison treatments were applied at similar timings including Rinskor active alone (24 and 30 g rate), tank mixture of Rinskor + penoxsulam (25 + 40 g rate), Rinskor + Cyhalofop (24 + 320 g rate), and several standard herbicides in the market place. All application timings were made early postemergence up to three days before the addition of the permanent flood. Results from the across trial analysis showed GF-3565 was very effective in controlling several key weeds such as barnyardgrass, sedges, alligatorweed, and ducksalad to name a few. The control of key grasses such as barnyardgrass, broadleaf signalgrass, and Amazon sprangletop was as good if not better than the stand alone active ingredients and competitive standards. ®™Trademarks of Dow AgroSciences, DuPont, or Pioneer and their affiliated companies or respective owners

Efficacy and Crop Safety of Rinskor™ Active (Florpyrauxifen-benzyl) in California Rice. Stephen F. Colbert*[1], Mauricio Morell[2]; [1]Corteva Agriscience, Escalon, CA, [2]Corteva Agriscience, Indianapolis, IN (499)

Rinskor™ active (florpyrauxifen-benzyl) is a new active ingredient in the arylpicolinate chemical class of synthetic auxin herbicides (WSSA group 4) from Corteva™ Agriscience being developed for post-emergence weed control in California rice. Loyant ™ CA (florpyrauxifen-benzyl 2.7%

EC) has activity on a wide range of broadleaf, sedge and grass weeds commonly present in California rice production fields at the target rate of 1.33 pt/A (40 g ai/ha). Efficacy and crop safety field testing was conducted in the Sacramento Valley water seeded rice production region over multiple years and locations. Loyant CA provided excellent control of common broadleaf weeds such as ducksalad (Heteranthera limosa), arrowhead (Sagittaria spp.), redstem (Ammannia spp.) and waterhyssop (Bacopa spp.) as well as good control of smallflower umbrella sedge (Cyperus difformis) and ricefield bulrush (Schoenoplectus mucronatus). Loyant CA efficacy against the common watergrass weeds in California rice (Echinochloa oryzoides, E. phyllopogon, and E. crus-galli) varied considerably across test locations from very good to poor control. Tank mix and/or rotation programs with other post-emergence rice herbicide options in California such as penoxsulam, bispyribac-sodium, cyhalofop and propanil resulted in very good to excellent control of most weeds present, including watergrass species. Little to no negative crop response was observed in tests at the target application rate of 1.33 pt/A. Tests conducted at exaggerated application rates, up to 4 times the target rate, resulted in visible but transient symptoms such as leaf curl and stunting but no statistically significant reduction in yield. Loyant CA with Rinskor™ active will provide California rice growers a new herbicide alternative for the control of a broad spectrum of weeds, applied alone or as part of weed control programs combining other herbicides, in mixtures or sequential applications.

Challenges of Weed Management in Rice Production in Canada. Kalidas Subedi*; Pest Management Center, Agriculture and Agri-Food Canada, Ottawa, ON, Canada (500)

Rice (*Oryza sativa L*.) is a completely new crop in Canada, which was introduced in the Fraser River Valley of British Columbia (BC) in 2009, as a test crop for sake production. Both sake and table purpose rice were tested and demonstrated to be successfully grown in this region and also in southern Ontario. However, area under rice production in Canada remained stagnant over years mainly because of lack of suitable crop management practices; primarily the weed control. In the absence of registered herbicides, manual and mechanical weeding are the only means of weed control in rice. These options are not only expensive, availability of appropriate equipment and labor are other constraints; weed control becoming the most costly operation of rice production. On the other hand, because of its limited acreage, herbicide companies have limited or no interest on herbicides testing as it involves high financial risk where returns on investment for new herbicides testing can be recouped. Barnyardgrass (BYG; *Echinochloa crus-galli*) was considered as the major weed problem in rice until 2016. Accordingly, the growers selected barnyardgrass control in rice as a “minor use project”. In 2016, an herbicide screening study was initiated which included four herbicides. Among these, quinclorac was found to be more effective against BYG and safe on rice. Residue and efficacy data generation for quinclorac are on-going. However, weed flora keep on changing; by 2018, new weed species such as smart weed (*Polygonum coccineum* Muhl), European water plantain or common water plantain or mad dog weed (*Alisma plantagoaquaticum*), sedges (*Eleocharis palustris* var. obtuse and *Trichophorum pumilum;* dwarf clubrush), horse tail (*Erigeron canadensis*) and several other species have started to invade and colonize rice fields in the absence of effective control measures. An herbicide screening study has been initiated against these emerging new weed species. Herbicides registration is a lengthy process. For the registration of a given herbicide, magnitude of residue, efficacy and crop safety data are required. Generation of such data requires a minimum of 4 years and involves substantial financial cost. Until effective solutions to these weeds are available, growers are facing a dilemma of abandoning the crop, which has a potential to expand in Canada. Rice production practices in Canada, emerging weed issues and evolution of weed flora in rice production are illustrated and Pest management Centers' efforts in regulatory data generation are discussed.

Efficacy of Metamitron Applied PRE in the High Plains Sugar Beet Production Region. Andrew R. Kniss*; University of Wyoming, Laramie, WY (501)

There are currently no effective herbicides for managing glyphosate- and ALS-resistant kochia (*Bassia scoparia*) and Palmer amaranth (*Amaranthus palmeri*) in sugar beet. In 2019 the herbicide metamitron was evaluated for crop safety and herbicide efficacy. The study was established in two locations in 2019: Lingle, WY with common lambsquarters (*Chenopodium album*) and redroot pigweed (*Amaranthus retroflexus*) being the dominate weeds, and Scottsbluff, NE with Palmer amaranth and common lambsquarters being dominant. Cycloate (3.36 kg ai ha^{-1}), ethofumesate (1.47 kg ai ha^{-1}), metamitron (2.8, 5.6, and 7 kg ai ha^{-1}), and metamitron (5.6 kg ai ha^{-1}) + ethofumesate (1.47 kg ai ha^{-1}) were applied PRE. Metamitron (5.6 kg ai ha^{-1}) + ethofumesate (1.47 kg ai ha^{-1}) was applied PRE followed by (fb) either ethofumesate (2.21 kg ai ha^{-1}) at the sugar beet two true leaf (2TL) stage, acetochlor (1.26 kg ai ha^{-1}) at 2TL, ethofumesate (2.21 kg ai ha^{-1}) at 2TL stage fb acetochlor (1.26 kg ai ha^{-1}) at 8TL, or acetochlor (1.26 kg ai ha^{-1}) at 2TL and 8TL. A non-treated check and weed-free check were included. Any treatment containing metamitron provided control similar to the weed-free check at the Lingle location. Metamitron followed by ethofumesate or acetochlor provided control similar to the weed-free control in Scottsbluff. At both locations metamitron alone provided control past 4 TL (2.8 kg ha ai^{-1}) and 6TL (5.6 kg ha ai^{-1}), while metamitron PRE fb acetochlor POST provided season-long weed control without the use of glyphosate POST.

Volunteer Corn Management with Fluazifop + Dicamba Tank Mixtures in Dicamba Tolerant Soybean. Marty Schraer*[1], Peter Eure[2], Thomas H. Beckett[2], Marshall Hay[3], Sudeep Matthew[2], Ethan T. Parker[3]; [1]Syngenta, Meridian, ID, [2]Syngenta, Greensboro, NC, [3]Syngenta, Vero Beach, FL (502)

Volunteer corn can significantly reduce soybean yield if left uncontrolled. Soybean yield loss caused by volunteer corn is dependent on the density and duration of interference. Management of volunteer corn in soybean includes reducing corn grain losses at harvest, tillage, cultivation, and chemical control. Use of Group 1 herbicides in soybeans to control glyphosate tolerant volunteer corn is common. Commercialization of dicamba tolerant soybean (*Glycine max* L. (Merr.)) increased the frequency of dicamba and Group 1 herbicide tank mixtures for control of glyphosate tolerant volunteer corn (*Zea mays* L.). Previous research documented the antagonism of monocot control when dicamba is added to Group 1 herbicides. Therefore, the objectives of this research were to (1) Evaluate Fusilade® DX (fluazifop-P-butyl) herbicide volunteer corn control with and without dicamba (2) Discuss factors that influence volunteer corn control when using Fusilade DX + dicamba tank mixtures. This research concluded that Fusilade DX is an effective tool for managing volunteer corn in soybeans when tank mixed with and without dicamba. Volunteer corn management may also be influenced by corn height, tank mix partners, and adjuvants.

Tirexor (Trifludimoxazin): Next Generation Burndown Update - US. Douglas Findley*[1], Cletus C. Youmans[2], Steven Bowe[3]; [1]BASF, Rolesville, NC, [2]BASF, Dyersburg, TN, [3]BASF, Research Triangle Park, NC (562)

Tirexor™ herbicide (Trifludimoxazin) [1,5-dimethyl-6-thioxo-3-(2,2,7-trifluoro-3,4-dihydro-3-oxo-4-prop-2-ynyl-2*H*-1,4-benzoxazin-6-yl)-1,3,5-triazinane-2,4-dione] is a new inhibitor of protoporphyrinogen IX oxidase (PPO or Protox). Trifludimoxazin is very active when applied PRE or POST on dicot/broadleaf weeds including *Amaranthus* spp., *Ambrosia*, *Chenopodium*, *Conyza*, *Lamium*, *Oenothera* and *Stellaria*. In addition, Trifludimoxazin can control PPO resistant *Amaranthus* biotypes which are not controlled by currently registered PPO inhibitors like fomesafen, sulfentrazone, or flumioxazin. The combination of trifludimoxazin plus saflufenacil (Voraxor™) improves the burndown effectiveness and spectrum of weeds controlled compared to either ai alone, and the combination will be an important tool for resistance management. Trifludimoxazin is expected to receive registration in key countries for use in burndown applications ahead of soybeans, corn, wheat and other crops in addition to total vegetation management.

Tirexor® a New (PPO) Herbicide to Manage Weed Resistance in Argentina. Teofilo Bustingorri*; BASF Argentina SA, Buenos Aires, Argentina (563)

For more than 20 years, Argentina has been augmenting weed control strategies to control glyphosate resistant weeds. However, many of the herbicides used in tank mixtures with glyphosate are now selecting for weed biotypes that are resistant to more than one herbicide site of action. Auxin mimic herbicides and inhibitors of ALS and ACCase are among the most important herbicides used for control of glyphosate resistant weeds. However, weeds like Italian ryegrass (*Lolium perenne*), birdsrape mustard (*Brassica rapa*), shortpod mustard (*Hirschfeldia incana*), smooth pigweed (*Amaranthus hybridus*), johnsongrass (*Sorghum halepense*), and plumeless thistle (*Carduus acanthoides*) now have biotypes that are not only resistant to glyphosate, but are also resistant to one of the aforementioned modes of action meant to manage glyphosate resistant biotypes. This presentation will demonstrate the severity of the herbicide resistance in Argentina and how Tirexor® will be a key active ingredient to help manage these issues.

Tirexor Herbicide: Tirexor + Kixor for Pre-seed Burndown Weed Control in Cereals and Pulse Crops in Western Canada. Mark Oostlander*[1], Ethan Bertholet[2], Lyle Drew[2], Brittany Hedges[1], Brendan Metzger[3]; [1]BASF, Calgary, AB, Canada, [2]BASF, Saskatoon, SK, Canada, [3]BASF, Winkler, MB, Canada (564)

A preplant burn down application of glyphosate is a critical step in the weed management program of the no till/ minimum till cropping system in Western Canada. With the incidence of glyphosate resistance on the rise, and the inherent weakness of glyphosate on specific weed species, it has become common practice to add an additional product (add-in) as a tank mix with glyphosate for pre-seed burndown applications. BASF introduced saflufenacil (KIXOR®) herbicide in 2010 as a pre-seed/ preemergence tank mix partner with glyphosate for control of key weeds, such as volunteer glyphosate tolerant canola, and glyphosate resistant weeds such as kochia. BASF has recently developed a new PPO herbicide trifludimoxazin (TIREXOR™) that will further support this pre-seed use segment. The combination of saflufenacil and trifludimoxazin in a 2:1 ratio (VORAXOR™), improved the burndown and residual control spectrum over equivalent rates of saflufenacil applied alone. The improved efficacy of VORAXOR™ from utilizing PPO's from 2 different chemical classes (Pyrimidinedione/ Triazolone), will allow it to be a key tank mix partner for glyphosate in the pre-seed burndown use segment of Western Canada.

Luximo - A Soil Active Residual Herbicide as a Novel Resistance Management Tool. Helmut Kraus*[1], Stuart J. Kevis[2], Giuseppe Allegretta[3], Laurent Picard[3], Ulrike Anders[3], Sascha Schlaefer[3], Sudhakar Kandru[4], Andreas Landes[3], Gerd Kraemer[3], Bernd Sievernich[5], Ruth Campe[3], Ian Francis[6]; [1]BASF Corporation, Durham, NC, [2]BASF Plc, Bury St. Edmunds, United Kingdom, [3]BASF SE, Limburgerhof, Germany, [4]BASF South East Asia Pte. Ltd., Singapore, Singapore, [5]BASF SE, Limburgehof, Germany, [6]BASF Australia, Tamworth, Australia (565)

Growing grass weed resistance to post-emergence graminicides has seen a shift to soil active residual alternatives in the production of winter cereals, especially Western Europe and Australia. To combat herbicide resistance, novel mode of action herbicides form an integral part of the Integrated Weed Management (IWM) toolbox. Following the successful mode of action elucidation of cinmethylin (tradename Luximo®), which has been shown to inhibit fatty acid thioesterase (FAT), the focus of research at BASF shifted to understand the ADME properties of the molecule. Results demonstrate that adsorption, distribution and metabolism of the active ingredient differs between the target crop and blackgrass (*Alopecurus myosuroides)* / ryegrass (*Lolium rigidum, Lolium multiflorum*), which helps explain the crop selectivity and grass weed efficacy behavior of the molecule. Furthermore, in the context of the novel mode of action and resistance management, internal work and multiple collaborations have aided in assessing and monitoring the risk of target / non-target site resistance development. Trials have demonstrated that cinmethylin is capable of controlling multi-resistant ryegrass and blackgrass populations originating in the target geographies Western Europe and Australia. Furthermore, blackgrass genome sequencing has shown that FAT A and B protein sequences are highly conserved across multiple biotypes, which leads to conclude that the risk of target site resistance development is moderate to small.

Introducing Luximo - A New Dawn for Black-grass Control in the UK. Stuart J. Kevis*; BASF Plc, Bury St. Edmunds, United Kingdom (566)

Black-grass (*Alopecurus myosuriodes*) is the number 1 pest for UK arable farmers. Shortening rotations, over reliance on contact chemistry and a weed that is capable of adapting to agricultural practises has meant that in the last 25 years black-grass has become the greatest threat to economical return for the UK arable farmer. Integrated Weed Management (IWM) has to become the standard practise going forward and part of that solution is a new herbicide from BASF with a new mode of action and high activity against black-grass. Luximo® is a new dawn for black-grass control for UK farmers and for European farmers with grassweed problems, the first new mode of action against black-grass in the last 30 years provides an exciting new tool just when farmers need it as old chemistry becomes resistant or is withdrawn due to regulatory guidelines.

Luximo: A New Mode of Action (MOA) Pre-emergence Herbicide for the Control of Annual Ryegrass (*Lolium rigidum* Gaud.) and Other Monocotyledon Weeds in Cereals in Australia. Ian Francis*; BASF Australia, Tamworth, Australia (567)

Luximo - A new mode of action (MOA) pre-emergence herbicide for the control of annual ryegrass (*Lolium rigidum* Gaud.) and other monocotyledon weeds in cereals in Australia Ian Francis, Marco Montagna, Russell Ison, Gavin Heard BASF Australia Ltd, Level 12, 28 Freshwater Place, Southbank, Victoria 3006, Australia (ian.francis@basf.com) Summary With many weeds resistant to common herbicide active ingredients (PSII-, ALS- and ACCase-inhibitors), farmers around the world are seeking new weed management options. In Australian winter cereals there has been a shift away from reliance on post-emergence graminicides to an increased emphasis on pre-emergence applications. Cinmethylin currently belongs to the cluster of herbicides with an unknown mode of action (HRAC Group Z). However, new research from BASF has identified this molecule to act *via* a totally new mode of action. Luximo Herbicide (750g/L cinmethylin) was tested as a pre-emergence herbicide in Australia during the 2014-18 growing seasons. Its efficacy and crop safety was evaluated at different application timings: incorporated by sowing (IBS), post-sowing pre-emergence (PSPE) and early post-emergence (EPE). Field trials were conducted (at various rates,) across the main cereal growing regions of Australia, targeting a number of monocotyledon weeds. Compared, primarily, to pyroxasulfone and S-metolachlor + prosulfocarb, cinmethylin demonstrated effective control of annual ryegrass *(Lolium rigidum* Gaund.) including resistant biotypes. Furthermore, good activity was displayed against other cool season grasses such as wild oat (*Avena* spp.), brome grass (*Bromus* spp.) and barley grass (*Hordeum* spp.). Different crops showed variable level of tolerance to cinmethylin, which was related to parameters such as soil application timing, conditions at sowing, sowing depth and rainfall patterns after sowing. Furthermore, cinmethylin was screened in the laboratory to determinate efficacy on annual ryegrass (*L. rigidum* Gaud.) resistant to other modes of action, showing high levels of control on all tested biotypes. Keywords: Luximo, Luximax, cinmethylin, pre-emergence, cereals, annual ryegrass

Weed Control in Dicamba-Tolerant Soybean in Southwest North Dakota. Caleb D. Dalley*, Daniel Guimaraes Abe; North Dakota State University, Hettinger, ND (568)

In southwest North Dakota, the area being planted to soybean is increasing each year. While still a relatively minor crop in the region, it has proven to be a good rotational crop for many growers. When compared with eastern North Dakota, there are increased challenges to growing soybean in the southwest region of North Dakota where the climate is drier and no-till cropping practices are utilized to preserve soil moisture. Winter annual and tough to control spring annual weeds are one of these challenges as many of the weeds have inherent or acquired tolerance to commonly used herbicides. The introduction of dicamba tolerant soybeans gives growers another tool in controlling these weeds. Two trials were conducted in the summer of 2019 to compare different approaches to herbicide weed management. In the first trial, several different preplant burndown treatments were compared for controlling winter annual and spring annual weeds. Treatments included glyphosate alone (1.12 and 1.68 kg ha-1), and glyphosate (1.12 kg ha-1) tankmixed with flumioxazin, flumioxazin + pyroxasuflone, flumioxazin + pyroxasulfone + metribuzin, flumioxazin + pyroxasulfone + metribuzin + pendimethalin, sulfentrazone + S-metolachlor, sulfentrazone + pyroxasulfone, sulfentrazone + metribuzin, saflufencil + pendimethalin, and saflufencil + acetochlor. These treatments were followed with a POST application of glyphosate and dicamba, across all treatments at 4 weeks after planting to control any weeds that escaped to preplant burndown or emerged afterward. At 2 WAT, all treatments controlled annual grasses (volunteer wheat, downy brome, Japanese brome) 95% or more, except tank-mixes containing metribuzin and combinations of sulfentrazone + metolachlor. In these treatments there appear to be some antagonism for grass control. Glyphosate alone controlled kochia 70 and 79%, respectively, at 1.12 and 1.68 kg ha-1. Tankmixes of glyphosate all controlled kochia 80 to 91%. Wild buckwheat was controlled 70 and 72% with glyphosate alone, respectively, at 1.12 and 1.68 kg ha-1. Most tank mixes increased wild buckwheat control to greater than 80%. Prickly lettuce was controlled 76 and 88% with glyphosate at 1.12 and 1.68 kg ha-1, respectively. Tank mixes containing flumioxazin or saflufencil increased prickly lettuce control to 96% or more, with tank mixes containing sulfentrazone increased control to 88 to 96%. Soybean yield was 22 to 25 bu/A for all herbicide treatments, with no statistical differences between treatments. All herbicide treatment resulting in yields greater than in the untreated control (14 bu/A). In the second trial, several different POST herbicide treatments were compared for weed control. In this trial, glyphosate was applied prior to planting to control weeds that had emerged prior to planting. POST treatments were applied on July 8, 2020, four weeks after planting. Weeds in the plots were 4 to 6 inches in height at the time of application, and soybean were at the V5 growth stage. Treatments included glyphosate (1.12 and 1.68 kg ha-1), dicamba, glyphosate + dicamba, glyphosate + fluthiacet-methyl + pyroxasulfone, imazethapyr, glyphosate + imazethapyr, and dicamba + imazethapyr. At 5 WAT, all treatments controlled green foxtail 92% or more with the exception of dicamba, imazethapyr, and dicamba + imazethapyr. Glyphosate alone (1.12 and 1.68 kg ha-1) controlled kochia 63 and 82%, respectively. Kochia was controlled 83 to 89% with other treatments, with the exception of glyphosate + fluthiacet-methyl + pyroxasulfone (55%) and imazethapyr (43%). Wild buckwheat control was only fair with most treatments, although glyphosate + dicamba (81%) and dicamba + imazethapyr (85%) provided the best control of this weed. Wild buckwheat was starting to vine at time of application and was past the ideal stage for control. All herbicide treatments increase soybean yield compared to the untreated control, although yield was lowest in the imazethapyr treatment, like due to the poor control of green foxtail and kochia. Weed control in soybean grown in southwestern North Dakota will require a good preplant burndown treatment followed by a POST application in order to maximize soybean yield. The herbicide components utilized will need to be matched to the weeds present at time of application. Dicamba tolerant soybean offers an additional herbicide that could be utilized to control tough weeds such as kochia and wild buckwheat.

Evaluating Weed Control and Crop Safety of a Premix of Dicamba and Pyroxasulfone in Dicamba-resistant Soybean in Nebraska. Ethann R. Barnes*[1], Brady Kappler[2], Amit J. Jhala[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]BASF, Eagle, NE (569)

Herbicide-resistant weeds are a major management problem for row crop producers in Nebraska. A number of weed populations have developed resistance to glyphosate and/or ALS-inhibiting herbicides. Dicamba-resistant soybean were introduced in 2017 allowing the use of dicamba in weed management programs. The use of multiple herbicide sites of action can delay the development of herbicide-resistant weed populations including resistance to dicamba. Dicamba-resistance has been confirmed in a population of Palmer amaranth (*Amarathus palmeri* S. Watson) resistant dicamba and 2,4-D. Evaluation of dicamba based pre-mixes and tank-mixes with multiple effective sites of action is needed to delay further evolution of resistant weed populations. Feld experiments were conducted at the University of Nebraska-Lincoln South Central Agricultural Laboratory near Clay Center, Nebraska to evaluate a pre-mix of dicamba and pyroxasulfone at different application timings. Herbicide treatments were evaluated in a randomized complete block arrangement with 4 replications. Treatments included a non-treated control, dicamba/pyroxasulfone, and other foliar-active POST herbicides applied PRE and POST to VE, V3, and V5 soybean growth stages. Weed control and soybean injury ratings were collected at 14, 21, and 28 days after PRE, VE, V3, and V5. Weed density and biomass were collected 50 days after V5 and soybean yield was harvest. PRE herbicide treatments including dicamba and pyroxasulfone provided >85% control of common waterhemp (*Amaranthus tuberculatus* (Moq.) J. D. Sauer), Palmer amaranth, velvetleaf (*Abutilon theophrasti* Medik.), and foxtail spp. (*Setaria* spp.) 42 DAT. Dicamba/pyroxasulfone plus glyphosate applied at the VE soybean stage resulted in >90% control of all aforementioned weed species 28 DAT. PRE herbicide treatments including dicamba and pyroxasulfone followed by dicamba plus glyphosate at the V3 soybean stage provided >88% control of all weed species. Dicamba/pyroxasulfone PRE followed by dicamba/pyroxasulfone at V3 provided 99% control of common waterhemp, Palmer amaranth, and velvetleaf 38 DAT; however, provided 0 to 76% control of foxtail spp. Dicamba/pyroxasulfone plus glyphosate at VE soybean stage followed by glyphosate alone or in tank mixture at the V5 soybean stage resulted in >96% control of all weed species in 2018 and >81% control in 2019 28 DAT. Applications of PRE followed by V3, VE followed by V5, and VE followed by V3 all resulted in 100% biomass reduction in 2018 and 41 to 96% biomass reduction in 2019. Yield ranged from 3939 to 4819 kg ha-1 in 2018 and 1417 to 1808 kg ha-1 in 2019 among herbicide programs with two applications. No soybean injury was observed from herbicides. This study concludes that a pre-mix of dicamba and pyroxasulfone provides effective control of broadleaf weeds as PRE or POST in dicamba-resistant soybean when used in multiple application herbicide programs.

Guayule (*Parthenium argentatum*) Response to Preemergence Herbicides. William B. McCloskey*[1], Guangyauo Sam Wang[2], Bryan C. Pastor[1]; [1]University of Arizona, Tucson, AZ, [2]Bridgestone Americas, Inc, Eloy, AZ (570)

Guayule is a desert adapted plant from the Chihuahuan Desert in North America that has been used for centuries by native peoples in Mexico and Central America, and in the last 100 years by U.S. companies as source of natural rubber. Weed control is a significant barrier to commercial rubber production from guayule. Guayule seedlings have little tolerance to broadleaf postemergence herbicides except for some PPO inhibitors such as carfentrazone-ethyl. Previous studies found that guayule transplants could tolerate row crop rates of pendimethalin applied after transplanting and incorporated with irrigation water. Thus, studies were initiated to determine guayule seedling tolerance to acetochlor, bensulide, ethalfluralin, pendimethalin, metolachlor, and sulfentrazone at various sites with different soil textures. The herbicides were either incorporated prior to or after bed formation or applied preemergence after seeding and incorporated with the germinating irrigation. Earlier studies used sprinkler irrigation to establish the crop but later studies used furrow irrigation. The experiments used randomized complete block designs with 5 or 6 replication and plots sizes of 4 rows (1 m rows) by 7.6 to 10.6 m long depending on the experiment. Preemergence herbicide treatments were applied using a tractor-mounted boom sprayer equipped with TeeJet® AI-11002 nozzles operated at 310 kPa (45 PSI) that delivered a spray volume of about 140 L/ha (15 gallons/acre) at 5 km/hr (3.1 MPH). Guayule tolerated pendimethalin and ethalfluralin better when the herbicides were mechanically incorporated into the soil rather than applied preemergence and incorporated with irrigation water. Higher rates of these herbicides were tolerated by guayule on clay loams compared to sandy loams. Similar results were obtained with acetochlor and bensulide but interestingly metolachlor and sulfentrazone were tolerated by guayule just as well whether the herbicides were mechanically incorporated or incorporated with irrigation water, and soil type had little impact. The results indicated that all six herbicides could be safely used during guayule seedling germination and establishment provided herbicides rates were adjusted to reflect the soil type present in the crop field.

Field Assessment of Flax Tolerance to Preemergence and Postemergence Herbicides. Caleb D. Dalley[1], Brian Jenks[2], Daniel Guimaraes Abe*[1]; [1]North Dakota State University, Hettinger, ND, [2]North Dakota State University, Minot, ND (571)

Flax is dual purpose crop grown for both its fiber and oilseed grown primarily in North Dakota and in the Canadian Prairie Provinces. In 2018, North Dakota accounted for 85% of flaxseed production in the US, with minor plantings in Montana and South Dakota. Few herbicides are registered for weed control in flax seed due to its small acreage. In 2018 and 2019, two experiments were conducted in Adams County in southwest North Dakota to evaluate PRE and POST herbicides for flax tolerance and weed control. In the PRE herbicide trial, pyroxasulfone (179 g ha^{-1}), sulfentrazone + pyroxasulfone (140+90 g ha^{-1}), acetochlor (1260 g ha^{-1}), metolachlor (1604 g ha^{-1}), sulfentrazone + metolachlor (140+1604 g ha^{-1}), flumioxazin + pyroxasulfone (70+89 g ha^{-1}), pendimethalin (1596 g ha^{-1}), flumioxazin (71 g ha^{-1}), and dimethenamid (945 g ha^{-1}) were evaluated. In 2018, due to low rainfall, little or no injury was observed for most herbicides, with the exception being acetochlor, with injury of 8% and 17% at 27 and 58 DAT, respectively. However, in 2019, with above normal rainfall, injury of 67% was observed at 65 DAT for flumioxazin and flumioxazin + pyroxasulfone treatments. Stand counts were also affected by these treatments and yield was reduced by nearly half compared to the highest yielding treatment. In 2019, weed control was better overall than previous year due to more rainfall. Common mallow control was greatest in 2019 with flumioxazin plus pyroxasulfone (90% at 9 WAT), and was similar to sulfentrazone plus metolachlor (90%) and sulfentrazone plus pyroxasulfone (85%). Common mallow control was fair to poor with all other treatments. Most treatments controlled kochia (85 to 100%) in 2019, with the exception of acetochlor and metolachlor. In the POST trial, herbicides were applied 2 weeks after crop emergence. Bicyclopyrone plus bromoxynil was applied at two rates (37 + 175 g ai ha^{-1} and 49 + 233 g ha^{-1}), topramezone at two rates (12 and 18 g ai ha^{-1}), MCPA + bromoxynil (280 + 208 g ai ha^{-1}), bentazon (560 g ai ha^{-1}), imazamox (35 g ai ha^{-1}), and imazamox + bentazon (27.9 + 446 g ha^{-1}). In 2019, topramezone + bromoxynil + MCPA (18 + 280 + 280 g ha^{-1}) was also included. Application of bromoxynil plus bicyclopyrone resulted in severe injury to flax (61 to 81% in 2018 and 18 to 58% in 2019), and reduced flax yield 38 to

46% in both years, compared with the highest yielding treatment. Topramezone caused minor injury to flax, but this injury did not reduce yield. Imazamox alone caused moderate injury to flax (29% in 2018 and 39% in 2019 at 2 WAT), but when tank-mixed with bentazon, this injury was reduced to 18% and 10%, in respective years. In 2019, topramezone + bromoxynil + MCPA caused moderate injury to flax (25%), but this injury also did not reduce yield. Imazamox and topramezone + bromoxynil + MCPA treatments provided excellent control of common mallow and fair control of kochia and wild buckwheat and injury from treatments did not reduce yield. Results from these trials indicate that herbicides should be further explored in order to determine proper timing and benefits for weed control.

Plantain (*Plantago lanceolata* L.), in Red Clover (*Trifolium pratense* L.) Grown for Seed. Kyle Roerig*, Andrew G. Hulting; Oregon State University, Corvallis, OR (572)

Narrowleaf plantain is a significant impediment to red clover seed production in western Oregon. Red clover seed production provides an important opportunity for growers in a region dominated by grasses grown for seed and wheat to rotate to a dicot crop and control problematic monocot weeds. For the rotation to remain successful, the economic value of red clover seed production must be retained. Seed quantity (yield) and seed quality are required for profitable red clover seed production. Narrowleaf plantain affects both of these negatively. In addition to reducing seed yield through competition, narrowleaf plantain produces seeds very similar in size and shape to red clover. To obtain a pure seed lot, red clover contaminated with narrowleaf plantain must be cleaned more aggressively causing red clover seed to be lost in the process, thus increasing costs of production and decreasing returns. Herbicides currently registered for red clover seed production do not adequately control narrowleaf plantain. NSTKI-012, an inhibitor of phytoene desaturase, was applied preemergence to a new planting of red clover and at the two-trifoliate stage of clover. Narrowleaf plantain was planted in the plots at the same time as the clover. Preemergent NSTKI-012 provided 60-70% control of plantain, but resulted in unacceptable crop injury. NSTKI-012 applied either alone or in tankminx at the two-trifoliate clover stage provided 88-100% control. NSTKI-012 tankmixed with flumetsulam, 2,4-DB, pronamide, and MCPA amine provided red clover yields equivalent to the untreated plot (at p-value 0.05), while NSTKI-012 tankmixes with paraquat and oxyfluorfen reduced crop yield.

WSWS PROJECT 4: TEACHING AND TECHNOLOGY TRANSFER

WSSA SECTION 7: TEACHING AND EXTENSION / TEACHING AND TECHNOLOGY TRANSFER

Herbicide Diversity Calculator: Interactive Web App That Estimates the Risk of Herbicide Resistance. Andrew R. Kniss[1], Albert T. Adjesiwor*[1], Nevin Lawrence[2]; [1]University of Wyoming, Laramie, WY, [2]University of Nebraska-Lincoln, Scottsbluff, NE (389)

Using effective herbicide mixtures is one of the commonly recommended practices for managing herbicide-resistant weeds. However, determining which herbicide combinations will provide effective broad-spectrum weed control at an affordable cost while also providing effective proactive resistance management can be cumbersome. We developed an interactive web application (bit.ly/HerbRisk) that qualitatively estimates the risk of herbicide-resistant weed evolution based on herbicide programs entered by the user. The model was coded in the R programming language, and a web interface was added using the shiny development environment. The app has a user-friendly interface that allows farmers, agronomists, or researchers to select the crops and herbicide programs they plan to use over a 4-year period, then estimates herbicide resistance risk score for each herbicide site of action chosen. Herbicide efficacy data was estimated from a variety of sources for single site of action (SOA) and premixed herbicides registered for use in sugarbeet, corn, dry bean, small grains, and soybean. Because the evolution of herbicide resistance is a multi-year process, the model requires users to choose crops and herbicide programs for a 4-year period before it will provide risk estimates. Once herbicides are chosen for all four years, and a weed species is selected, the model calculates herbicide efficacy, cost of control, and an herbicide resistance risk score for each selected herbicide SOA. Risk scores are currently on a scale of 0 to 4. The minimum score of 0 means the herbicide site of action was never used during the 4-year period. Each time an effective SOA is used on the target weed, that SOA is initially given a score of 1; however, this score is reduced if a second effective SOA is applied in the same year. If a SOA is selected each of the four years, and in all four years there was no effective second SOA selected, this would result in the maximum risk score of 4. The risk score for each SOA within a year is reduced by an amount that depends on the efficacy of the second SOA. At this time, the risk scores calculated by the model should be considered qualitative - that is, a risk score value of 0.5 is not necessarily twice as likely to select for resistance as a risk score of 0.25. The short to medium-term goal is to add rotation restrictions and extend the model to include other crops and weeds. The eventual is goal is to provide quantitative risk estimates as well as herbicide and crop rotation recommendations for effective herbicide resistance management.

Glyphosate and Seed Germination, is the Jury Still Out? William T. Cobb*; Cobb Consulting Services, Kennewick, WA (390)

Paper withdrawn

Lessons Learned: Implementing Ventenata and Medusahead EDRR on a Mixed Ownership Landscape. Andrew Cassiday*[1], Brian Mealor[2], Luke Sander[3], Lindy Garner[4], Oakley Ingersoll[1], Carrie Rogaczewski[5]; [1]USDA NRCS, Sheridan, WY, [2]University of Wyoming Sheridan Research and Extension Center, Laramie, WY, [3]Sheridan County Weed and Pest, Sheridan, WY, [4]USFWS, Great Falls, MT, [5]Sheridan County Conservation District, Sheridan, WY (391)

In the summer of 2016, the first known self-sustaining populations of Ventenata, *Ventenata dubia* (Leers) Coss., and medusahead, *Taeniatherum caput-medusae* (L) Nevski. in the Great Plains ecoregion were identified in Sheridan County, Wyoming. Since then the Northeast Wyoming Invasive Grasses Working Group has implemented a collaborative, multi-stakeholder Early-Detection/Rapid-Response (EDRR) approach to manage these invasive annual grasses across a mixed ownership landscape. From its beginning the collaborative team has used the EDRR framework to guide its actions to prevent further establishment of these species, reduce transport of seed, raise community awareness, understand existing population extents, and implement best available treatments to reduce seed production. All of these actions work toward the Group's goal to achieve local eradication of medusahead and containment of *Ventenata* because of the substantial threat to grassland ecosystems represented by both species. The Group's efforts have evolved in scope as the known extent has expanded, but the framework has remained constant. The Group's scope has expanded to a multi-focal, landscape-scale containment strategy over three counties in northeast Wyoming. Coordination activities have expanded regionally to support efforts with agencies and landowners in Montana and South Dakota. The collaboration has been successful in navigating a number of challenges, including technically, administratively, logistically and socially. Numerous private landowner, NGO, local, state, and federal agency partnerships have been the core of the success and the ongoing engagement in making headway in combatting these species. Data gathering, methods testing, and best-practices development also continue to be needed outcomes of the Group's efforts because of the lack of data on these species in this region and climate. Going forward, the Group is poised to leverage efforts into full-time coordination, methods standardization, and data warehousing. This continuing evolution will be key to sustaining success as focus shifts from reconnaissance, mapping, and treatment, to monitoring and coordination of retreatments to ensure local eradication by seedbank depletion.

Machine Vision: A Promising Tool for Smart Farming. Aman Rana*, Jeffrey Derr; Virginia Tech, Virginia Beach, VA (392)

Traditional methods of weed scouting have been known to use manual labor. This process is time consuming, costly and contributes to major yield losses. To solve this using machine vision, researchers often use remote sensing weed maps, but this is ineffective due to problems such as solar and cloud cover in satellite imagery. Unmanned Aerial System (UAS) can resolve problems associated with satellite maps as they fly at low altitude (<400 feet) and acquire localized data in real time. Unmanned Aerial Systems are widely used not only for military operations, but for many civil operations. Unfortunately, most UAS do not have good payload capacity. Therefore, UAS acquired data further processed for vital information at ground stations or laboratories, which is time consuming and laborious . In recent times, image processing techniques are used in precision agriculture to identify weed problems. There are still many challenging problems associated with weed scouting to solve in machine vision. The objective of this research project was to advance weed scouting using machine vision equipped UAS. There were a lot of color variations that existed in all plant species. These variations made image processing more complex. Researchers used array of pixels from target weed species to identify respective weed species in an open field in real time. Microsoft VB Scripts program was used to write algorithm and process image. Acquired pixels were pre-processed to eliminate soil background and duplicate pixels. Thereafter, preprocessed an array of pixels was compared with an array of pixels in image or even in live camera feed. Image processing system successfully compared and identified target weed species in existing plant population. Results were quite promising in the sense that machine vision equipped drones will be a potential way for weed scouting in the near future. Researchers demonstrated that specifically customized image processing algorithms can successfully segment crops and weeds in various growth stages, and also identified limitations of this technique that can further guide future research.

Winfield® United Clinics: Show and Tell for 21st Century Agriculture. Gregory K. Dahl*[1], Ryan J. Edwards[2], Lillian C. Magidow[2], Annie Makepeace[2], Genevieve M. Mrnak[2]; [1]WinField United, Eagan, MN, [2]WinField United, River Falls, WI (393)

Winfield® United and its legacy companies have found that "Show and Tell" methods to demonstrate improvement in crop production have been highly effective at gaining interest, understanding and product purchases. Winfield United along with their Retailers have put on over 3,700 Clinics in 2019 and is conducting thousands more Clinics in 2020. A Clinic is a value-added education conversation that leads to a sales conversation. Clinics engage a grower or retail seller around a defined agronomic problem by sharing proprietary data and insights that showcase solutions. Focus products vary by Clinic topic, usually with an emphasis on adjuvants or plant nutrition products. The Clinic strategy complements a retail owner's strategy by discussing agronomic hot topics through presentations, conversations demonstrations and digital engagement. A particular strength of the Clinics strategy are the hands-on demonstrations which engage the audience members at a higher level. Each clinic topic has training information, demonstration materials and instructions, videos, handouts and talking point for presenters. The 2020 Clinics program focuses around key topics that are agronomically relevant and of interest to many growers. Topics include: 1. Early Season Corn and Soybean Management , 2. Response to Fungicide (RTF): Prioritizing Applications to Optimize Return on Investment, 3. Managing Soybean Traits with Adjuvants: Optimizing Dicamba, Enlist and Liberty platforms, 4. The Journey of the Droplet: Getting the Most Out of Your Tank Mix Investment, 5. Managing for Higher Yields: Understanding Key Nutrients and Timing by Crop and 6. Nitrogen Management.

2019 National Survey Results for the Most Common and Troublesome Weeds in Broadleaf Crops, Fruits, and Vegetables. Lee Van Wychen*; Weed Science Society of America, Alexandria, VA (394)

In 2019, weed scientists listed their five most common and five most troublesome weeds in the following 12 crops: 1) alfalfa, 2) canola, 3) cotton, 4) fruits & nuts, 5) peanut, 6) pulse crops, 7) soybean, 8) sugarbeets, 9) vegetables- cole crops, greens, 10) vegetables- cucurbits, 11) vegetables- fruiting, and 12) vegetables- other. Common weeds refer to weeds you most frequently see. Troublesome weeds are weeds that are the most difficult to control, but might not be widespread. The top five most common weeds among all broadleaf crops, fruits and vegetables surveyed were: 1) common lambsquarters, 2) pigweed species (not Palmer amaranth or waterhemp), 3) Palmer amaranth, 4) kochia, and 5) foxtail species. The top five most troublesome weeds among all broadleaf crops, fruits and vegetables surveyed were: 1) Palmer amaranth, 2) kochia, 3) common lambsquarters, 4) horseweed, and 5) nutsedge species.

The History and Future of Adjuvant Research and Education. Joe V. Gednalske[1], Gary Halvorson*[2]; [1]Council of Producers & Distributors of Agrotechnology, Washington, DC, [2]Council of Producers and Distributors of Agrotechnology, Washington, DC (395)

The US adjuvant business evolved out of researchers finding that some herbicides could be used safely on crops after they had emerged. Many herbicides benefited from additional additives to increase performance. The growth of adjuvants mirrored the rapid growth of post herbicides. Weed Science Researchers were leaders developing not only new adjuvant technologies but educating growers on use and training the next generation of adjuvant researchers. The history of the post emerge herbicide and adjuvant growth is discussed. The help of the Weed Science Society of America to promote more research and education on adjuvants is requested.

Using Plot Demonstrations to Improve Herbicide Decisions for Waterhemp in Iowa. Meaghan Anderson*[1], Angie Rieck-Hinz[2]; [1]Iowa State University, Nevada, IA, [2]Iowa State University, Clarion, IA (396)

Field days were held in June 2018 and 2019 with plot demonstrations to help farmers and advisers better understand the importance of using preemergence and postemergence herbicides, the importance of using multiple sites of action, and the importance of timing with postemergence herbicide applications for waterhemp control in Iowa. Follow-up surveys in fall 2019 were sent to attendees from the 2018 and 2019 field days with questions tailored specifically for farmers or ag retailers. Farmers reported a variety of challenges to managing herbicide resistance. The most commonly reported challenges to managing herbicide resistance were using multiple sites of action (25%), recognizing if a herbicide is effective (25%), effective timing for herbicide application (21%), and determining effective herbicide rates (17%). As a result of attending the field days, 60% of farmer attendees changed or planned to change their herbicide program, while 100% reported that they could better see the value of full herbicide rates, better understand the value of a preemergence herbicide, and better see the importance of timely application for postemergence herbicides. Future field days will continue to use plot demonstrations like these and will include non-chemical weed management practices like soybean row spacing and cover crops.

Survey of Rice Growing Practices in California Identifies Perceptions and Management of Weeds and Weedy Rice. Elizabeth Karn[1], Serena Bhagirath[1], Luis Espino[2], Whitney Brim-DeForest*[1]; [1]University of California Division of Agriculture and Natural Resources, Yuba City, CA, [2]University of California Division of Agriculture and Natural Resources, Oroville, CA (397)

Weedy rice (*Oryza sativa* f. *spontanea*) is an emerging weed in California rice production. To address weedy rice issues and improve extension, information is needed about the prevalence of growing practices that may contribute to or prevent weedy rice infestations, and about grower awareness and perceptions of weedy rice and other weed issues. Using a mail-in and online survey, information was gathered in spring 2019 from growers and pest control advisors about their rice production practices and knowledge regarding weedy rice. Among 157 survey responses, participants reported diverse rice production systems, growing practices, and weed management methods. Weedy rice was reported on only a small number of participants' farms (n = 12), and most participants did not consider weedy rice to be a serious issue. Most participants did use practices to prevent the spread of weedy rice onto land they manage, and these efforts hopefully will aid in preventing weedy rice from becoming a larger problem in the future.

An Update on Herbicide-Resistant Kochia and Palmer Amaranth in Western Kansas. Vipan Kumar*[1], Rui Liu[1], Taylor Lambert[1], Randall S. Currie[2], Phillip W. Stahlman[1]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Garden City, KS (398)

Kochia (*Bassia scoparia*) and Palmer amaranth (*Amaranthus palmeri*) are two most problematic broadleaf weed species in agronomic crops across central and western Kansas. Evolution of herbicide resistance to multiple modes of action (MOA) in both weed species pose a serious threat to the no-till dryland production systems in the region. The main objective of this paper is to provide a current state of knowledge on herbicide-resistant kochia and Palmer amaranth in central and western Kansas. Since the first discovery in 2007, glyphosate resistance is now fairly common among kochia populations. The EPSPS gene duplication has been found the basis of this widespread resistance to glyphosate. More recently, low to high level resistance (3 to 15-fold) to POST dicamba has also been identified in kochia populations from long-term research plots near Hays and Garden City. These populations have also shown low to moderate level (3- to 8.6-fold) cross-resistance to fluroxypyr herbicide. Furthermore, the same populations from Garden City, KS demonstrated high level resistance to PRE and POST applied atrazine (up to 134-fold) and metribuzin (up to 57-fold) in dose-response assays. A single point mutation Ser264Gly has been observed in the psb*A* gene conferring this high level resistance to atrazine and metribuzin. Herbicide screening on recently collected 20 kochia populations from western Kansas is underway to further understand the frequency and pattern of multiple herbicide resistance among field populations. Screening of 44 Palmer amaranth populations collected from 20 different counties across south central Kansas revealed glyphosate resistance in >50% of tested populations. In addition, resistance to chlorsulfuron, atrazine and mesotrione was found highly prevalent in those tested populations. Two Palmer amaranth populations have been reported with low-level resistance to 2,4-D (up to 3.5-fold) while one population also had reduced sensitivity to fomesafen herbicide. All randomly surveyed Palmer amaranth populations across southcentral Kansas were sensitive to field-use rate of POST dicamba; however, a single population surviving POST dicamba treatment has recently been identified from a long-term no-till research plots near Manhattan, KS. Increasing cases of multiple herbicide resistance urgently require the development of ecological-based integrated strategies (including effective PRE herbicides, harvest weed seed destructor, crop rotations, cultural practices, improved agronomic practices etc.) for controlling these multiple resistant kochia and Palmer amaranth populations in the region.

Weeds Week: Using Social Media to Teach About Weed Control. Jeanne S. Falk Jones*; Kansas State University, Colby, KS (399)

Social media is everywhere and our farmers and agronomy professional clientele are using it. Popular formats of social media are Facebook, Instagram, snapchat, twitter and YouTube. Each of these formats has its own advantages/disadvantages and its own audience. #WeedsWeek is a week of social media posts focused on weed science and helping farmers and agronomy professionals better understand how to control their troublesome weeds. #WeedsWeek is hosted on the K-State Sunflower District Agronomy facebook page and twitter account @CropsWithJeanne. The social media posts during #WeedsWeek include videos, infographics, contests, highlighting of K-State weed science resources and news articles. In addition, the tag #WeedsWeek is included in each post. The posts are focused on general weed science topics, herbicide resistance and on troublesome weeds in western Kansas (Palmer amaranth, kochia and tumble windmillgrass). #WeedsWeek was held in 2017, 2018 and 2020 during the week surrounding the K-State Weed Management School held in the area. This way, attention is also drawn to the in-person meeting, where farmers can attend to ask more weed control questions. The #WeedsWeek posts that garner the most interaction with clientele are contests and videos. Contests require feedback (comments or replies) from the clientele to enter the contest. In 2017, a contest on facebook with a photo, asking 'What herbicide could have caused this damage?' had 21 comments answering that question. Similar contests with 'Name the seedling weeds in this picture' and 'In Kansas, Palmer amaranth is resistant to how many groups of herbicides?' had 15 and 9 comments respectively. In addition, answers are posted to each question with a link to more information from K-State Agronomy on these topics. #WeedsWeek videos are also seen more often by clientele because the facebook algorithm shows videos more often than posts with text content only. A video highlighting the easy-to-use tables in the K-State Chemical Weed Control Guide had a reach of over 1300 people. That video was clicked on by 97 people to play it and there were 27 likes, comments or shares on it. By clientele interacting with a facebook page, additional posts from the page show up in their newsfeed. This causes increased traffic on the page and increased information from K-State Agronomy that is delivered to clientele.

WSWS PROJECT 5: BASIC BIOLOGY AND ECOLOGY
WSSA SECTION 9: BASIC BIOLOGY AND ECOLOGY

Predict Invasive Potential of a Weed Likely to Increase with Climate Change. Hannah Duff*, Bruce Maxwell; Montana State University, Bozeman, MT (311)

Annual wheatgrass (Eremopyrum triticeum) is an introduced, cool season, annual grass that recently established in disturbed areas of the Gardiner Basin of Yellowstone National Park. Local managers are concerned that annual wheatgrass is preventing the reestablishment of native perennials. Little is currently known about the reproductive capacity or spread of annual wheatgrass but it is suspected to be highly competitive with native species due to its winter annual lifecycle. Some studies predict that annual grass species will become more competitive with changing climate conditions, while others report inconsistent responses to rising temperatures. The goal of this study was to assess the invasive potential of annual wheatgrass with two temperature treatments (ambient and elevated) in the field in the Gardiner Basin using open-top chambers (OTCs). Lifecycle demographics were monitored in the field treatments and used to parameterize a lifecycle model. We found evidence for a temperature treatment effect on annual wheatgrass seedbank density and population growth rates using the lifecycle model. Annual wheatgrass seedbank density is projected to increase by 44.61% by year 5 at elevated temperature conditions compared to 8.74% at ambient temperature conditions. Annual wheatgrass population growth is projected to increase more rapidly (mean annual growth rate, *?* = 1.79) by year 5 at elevated temperature conditions than at ambient temperature conditions (mean annual growth rate, *?* = 1.1). Projected population growth rates at elevated temperature conditions had 0.8 probability of being greater than rates of controls after 5 years of simulated dynamics. Model simulated seedbank densities had 0.95 probability of being greater than densities under ambient conditions after 5 simulated years. In addition, we found that annual wheatgrass percent cover was negatively correlated (R2=0.5288, p=0.002) with three of six neighboring plant species, suggesting that native and nonnative plant cover was either negatively affected by the presence of annual wheatgrass or annual wheatgrass establishes where other species are infrequent. Climate change projections for the region suggest warming winters may favor the winter annual wheatgrass. Management options such as fire should be explored.

The Evolutionary Genomics of Herbicide-Resistant Weeds. Bridgit W. Vasiljevic*, Ulrich Lutz, Ilja Bezrukov, Detlef Weigel; Max Planck Institute for Developmental Biology, Tübingen, Germany (312)

The evolution of herbicide-resistant weeds is a predictable consequence of natural selection. Mechanisms underlying herbicide resistance are classified into two broad categories: the well-studied target-site-based resistance mechanisms (TSR), and non-target-site-based resistance mechanisms (NTSR) whose genetic determinants are poorly understood. Numerous studies have illustrated the quantitative nature of NTSR-associated traits. Owing to the high variability of NTSR, non- candidate-gene based approaches are necessary to elucidate the genetic basis underlying NTSR. In order to identify the natural modulators of glyphosate resistance, I am evaluating the differential response of over 100 Arabidopsis thaliana accessions to incremental doses of glyphosate for genome- wide association studies (GWAS). Preliminary analyses have hinted at a continuous phenotypic distribution suggesting the polygenic control of resistance. I will then conduct quantitative trait locus (QTL) mapping on segregating F2 populations derived from parental lines exhibiting extreme phenotypic responses. Combining both approaches will aid in resolving the complexity of genetic architectures underlying NTSR mechanisms and sets the stage for identifying causal loci in the evolution of NTSR after recurrent herbicide selection.

Do Certain Nutrients and Plant-Soil Feedbacks Affect *Ventenata dubia* (Ventenata) Seedling Growth? Michelle L. Majeski*, Catherine Zabinski, Lisa J. Rew, Jane Mangold; Montana State University, Bozeman, MT (313)

Ventenata [*Ventenata dubia (*Leers) Coss.], a winter annual, non-native grass, has become invasive in the intermountain Pacific Northwest. Recent research shows that ventenata abundance is higher in clayey soils with low phosphorous and potassium concentrations in sagebrush steppe plant communities. Further investigations into abiotic and biotic soil factors and ventenata invasion may provide insight about this species' success. Our objective was to test the effect of nutrient treatments and potential plant-soil feedbacks on ventenata seedling growth in a greenhouse setting. For the nutrient treatments, we used a full Hoagland's solution and two modified solutions, one without phosphorous (P) and a second without P and potassium (K). For the plant-soil feedback, we collected soil from a site where ventenata was growing and nearby where it was absent and used these two soils as inoculum into sterilized greenhouse soil. Two trials with three nutrient treatments (full, -P, -P-K) and three soil treatments (+field with ventenata, +field without ventenata, -field) were factorially arranged and replicated eight times in a greenhouse at Montana State University in Bozeman, MT. After 85 days, we collected above and belowground biomass along with shoot height and analyzed data with a linear model. Ventenata biomass was 25 to 32 times greater when grown with the +field soil compared to the -field soil, but whether or not the field soil came from an area where ventenata was growing was less important. Biomass was twice as high in the full nutrient treatment compared to the modified treatments. Ventenata shoot height was almost three times greater when grown in the +field soil as opposed to the -field soil, and it tended to grow highest with the full nutrient treatment. Our results suggest that soil microbes contribute to ventenata growth, and further soil biotic explorations should be pursued to help explain ventenata invasion.

Developing Growing Degree Day Models to Manage Annual Polygonum Species in Western Washington. Steven S. Seefeldt*[1], Chris Benedict[2], Brian Maupin[1]; [1]Washington State University, Mount Vernon, WA, [2]Washington State University, Bellingham, WA (314)

Abstract not available

EPSPS Gene Amplification Confers Glyphosate Resistance in *Bromus tectorum* (Downy Brome). Pragya Asthana*, Rachel J. Zuger, Rhoda Brew-Appiah, Karen Sanguinet, Ian Burke; Washington State University, Pullman, WA (315)

Glyphosate, as a non-selective, systemic, broad-spectrum herbicide has had many commercial applications for decades. Increased use has led to the evolution of glyphosate resistance, now reported in 31 weed species world-wide. Three downy brome (*Bromus tectorum* L.) biotypes, suspected of glyphosate resistance, were collected in Washington. Glyphosate dose responses performed at the rates of 420, 840, 1681, 3362, 6725, 13450 g ai ha^{-1} confirmed the suspected resistance exhibited by the resistant biotypes, ranging between 88 to 159-fold increase in GR_{50} values compared to a known field susceptible biotype (GR_{50} 498 g ai ha^{-1}). Quantitative PCR results supported 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase gene amplification as the likely molecular mechanism conferring glyphosate resistance in all three resistant downy brome populations. No mutations in EPSPS were found in any biotype. The EPSP synthase gene was amplified, on average, 14 to 18-fold with respect to the EPSP synthase copy number in the known susceptible biotype. The corresponding increase in EPSP synthase expression levels were found to be 7.5 to 9-times more than the susceptible. However, no correlation was observed between EPSP synthase copy number and expression levels in the resistant populations. Glyphosate resistance in downy brome will significantly impact the low-external input dryland wheat fallow systems practiced in Washington.

Escaping Proteolysis: A 27 Base Pair Deletion in AUX/IAA2 Degron Tail Confers Resistance to Auxinic Herbicides in *Sisymbrium orientale*. Marcelo Figueiredo*[1], Anita Küpper[2], Christopher Preston[3], Jenna Malone[4], Tijana Petrovic[4], Anireddy Reddy[1], Kasavajhala Prasad[1], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Bayer, Frankfurt, Germany, [3]University of Adelaide, Glen Osmond, Australia, [4]University of Adelaide, Adelaide, Australia (316)

Auxinic herbicides are important for controlling dicot weed species due their efficacy and selectivity in monocot crops. Sisymbrium orientale (Indian hedge mustard) is an important weed species in Australia reducing yields in crops and pastures. In 2005, a 2,4-D and MCPA resistant population was reported in the Port Broughton region in South Australia. AUX/IAAs are dynamic repressor proteins that regulate Auxin Response Factors (ARFs) to activate auxin related genes, and are also co-receptors for auxins and synthetic auxin herbicides. The degradation of AUX/IAAs is done by the enzyme complex E3, called SCFTIR1/AFB, which in the presence of auxin performs ubiquitination on AUX/IAA making it a target to proteasome 26S, an enzyme responsible for proteolysis on eukaryotes. An RNAseq study showed that a 27 bp deletion in AUX/IAA2 (IAA2) degron tail was correlated to the resistant phenotype. The mutant allele was functionally validated to confer 2,4-D resistance by transforming Arabidopsis thaliana with the IAA2WT and IAA2?27 alleles. Performing affinity binding analysis with SPR, the binding association between TIR1 in the presence of auxin was similar for both IAA2 versions; however, the resistant allele of the protein showed lower binding affinity and faster dissociation from TIR1 in the presence of IAA, 2,4-D and Dicamba. Our results suggest that the loss of 9 amino acids within the intrinsic disordered region located in the degron tail may reduce the capacity of IAA2 to "embrace" TIR1 in the presence of auxin, reducing ubiquitination rate, resulting in higher stability to repress auxin response factors and ultimately conferring resistance to 2,4-D.

Acetolactate Synthase Inhibitor Resistance in Ontario Populations of *Chenopodium album* L. Clement Mo*[1], Francois Tardif[2]; [1]University of Guelph, Markham, ON, Canada, [2]University of Guelph, Guelph, ON, Canada (317)

Common lambsquarters (*Chenopodium album* L.) is an annual dicot plant that is highly adaptable and competitive with major global crops. Left uncontrolled, common lambsquarters can cause a 55-95% and 60-75% yield loss in Ontario corn and soybeans, respectively. Long seed dormancy and high fecundity make this species persistent and hard to manage. Historical uses of acetolactate synthase (ALS) inhibitors, a group of herbicides that inhibit branched-chain amino acid production, were efficacious in common lambsquarters control. However, common lambsquarters was documented to be resistant to two subclasses of ALS inhibitors in Canada. Differential response to the ALS herbicide subgroups were examined in this study. Four post-emergent ALS inhibitor classes were evaluated against two susceptible and two suspected resistant populations of common lambsquarters at different biologically active rates. Above ground biomass was collected and dry weight was plotted to determine resistance factors. Cross-resistance was found between four of the five subclasses of this herbicide group, two more than previously documented. Thiencarbazone-methyl; a newer molecule, was more effective at controlling common lambsquarters populations than historically used ALS inhibitors. Pyrithiobac-sodium, currently not registered in Eastern Canada, also displayed control at rates much lower than field rate. Crude enzyme assays were performed to confirm resistance and determine the GR_{50} values. The results suggest that an underlying mechanism or mutation is responsible for the rapid development of acetolactate synthase resistance in Ontario populations of common lambsquarters.

Weighing the Mechanisms of Yield Loss: from the Bucket to the Field. Joe G. Ballenger*, Albert T. Adjesiwor, David A. Claypool, Andrew R. Kniss; University of Wyoming, Laramie, WY (318)

Weeds damage crops through a combination of resource and non-resource competition. Although most of these responses are well characterized, the contribution of individual factors are not well understood. The shade-avoidance response, a response to reflected far-red light from neighboring plants, is an important part of non-resource competition. However, the relationship between weed removal timing and amelioration of the shade avoidance response is unclear. Sugarbeets (*Beta vulgaris*) were grown with and without the presence of established Kentucky bluegrass (*Poa pratensis*) whose roots were blocked from interacting with the beets via plastic barrier. Shading of the sugarbeet plants was prevented through trimming to ensure the grass was shorter than the beet.

Grass was physically removed or added at various times during the study beginning at the 2 true-leaf stage to simulate weed removal and weed emergence, respectively. Weed-free and season-long weedy treatments were also included. If grass was present from sugarbeet planting to the 2 true-leaf stage, leaf and root biomass decreased by 30% and leaf number decreased by 25%. If grass was removed at any time between the 2 true-leaf stage and harvest, sugarbeet biomass production was not statistically different suggesting nearly all of the early-season yield loss attributable to shade avoidance occurred between sugarbeet planting and the 2 true-leaf stage. Shade avoidance can cause irreversible reductions in sugarbeet yield potential before the 2 true leaf stage.

Horseweed (*Erigeron canadensis*) Emergence Time and Over-winter Mortality. Erin Haramoto*[1], Ryan Collins[1], Anita Dille[2], Karla L. Gage[3], Reid Smeda[4], Brent Sunderlage[3]; [1]University of Kentucky, Lexington, KY, [2]Kansas State University, Manhattan, KS, [3]Southern Illinois University Carbondale, Carbondale, IL, [4]University of Missouri, Columbia, MO (319)

Emergence of horseweed (*Erigeron canadensis*) can occur in both the fall and the spring. Previous experiments in which seed from different horseweed populations was planted in common locations suggest that site-specific weather and edaphic conditions are the main drivers in determining horseweed emergence time, rather than genetic control. Cohorts of fall-emerging plants are subject to frost-heaving over the winter, a potential loss pathway of largely unknown and potentially variable magnitude. Fall-emerged plants may be too large for adequate chemical control if treated at soybean planting, leading to additional applications, crop competition, and yield loss. Predicting when this species will emerge, and the potential for over-winter mortality, will help inform management practices. The objectives of this experiment were thus to characterize horseweed emergence time across four mid-latitude states (Kansas, Kentucky, Illinois, and Missouri) and, for fall-emerged plants, to determine the potential for over-winter rosette survival. A common garden experiment was used to assess horseweed emergence time in KS, KY, IL, and MO, over 2017-18 and 2018-19. Two populations from each state were planted at one location per state in isolation rings. The number of emerged seedlings was counted twice per week until the following spring. Additionally, 80-200 individual rosettes from the native population were identified and flagged at each location in December 2018. Initial rosette diameter ranged from 10-130 mm. In spring 2019, plants were identified as alive or dead, and plant diameter was measured again for living plants. Binomial logistic regression was performed to determine whether initial plant diameter could predict rosette survival; data were analyzed separately by state. Plants that could not be definitively identified (i.e., either flags or plant number was lost over the winter) were not included in the analysis. In most site-years, common garden experiment emergence occurred primarily in the fall, with adequate fall precipitation also noted at most site-years. In three states (KS, KY, and MO), initial rosette diameter was an effective predictor of overwinter rosette survival. Initial plant diameter was similar in IL and MO (30.2 and 33.6 mm, respectively), but only 33% of plants survived in Illinois relative to 80% survival in MO. Rosettes in KY were larger than in IL and also had greater survival (68%). IL and KY experienced similar numbers of freeze/thaw events, though one event in KY persisted for much longer than in IL. Soil temperature was slightly higher in IL, while higher soil moisture was observed in KY. These findings suggest that fall is a key emergence time across these mid-latitude states, and that specific soil conditions related to soil type and weather could influence over-wintering success.

Status of Herbicide-Resistant Kochia (*Bassia scoparia*) and Palmer Amaranth (*Amaranthus palmeri*) in Colorado. Andrew D. Effertz*, Philip Westra, Eric P. Westra; Colorado State University, Fort Collins, CO (320)

Kochia (*Bassia scoparia*) is one of the most problematic weeds in Colorado. Herbicide resistance has been documented in kochia found in Colorado to a number of herbicide mode of actions dating back to the 1980s. Colorado State University began screening kochia for herbicide resistance in 2011 and continues to do so on a yearly basis. Atrazine resistance in kochia has been considered to be widespread, strong presences of glyphosate and dicamba resistance have been documented, and no fluroxypyr resistance has been found yet. While monitoring for kochia resistance, Palmer amaranth (*Amaranthus palmeri*) has been seen moving into Eastern Colorado. While in the early stages of monitoring for herbicide resistance in Palmer amaranth, atrazine and glyphosate resistance has already been found in the Northeastern part of the state. Continued screening of these two highly important agronomic weed species is important in order to monitor the spread and level of resistance to some of the more popular herbicides used to control them.

Exploring the Dynamics of EPSPS and Abiotic Stress Genes in Kochia. Philip Westra*[1], Andrew D. Effertz[1], Todd A. Gaines[1], Crystal D. Sparks[1], Eric L. Patterson[2]; [1]Colorado State University, Fort Collins, CO, [2]Michigan State University, East Lansing, MI (321)

Abstract not available

Invasive Annual Grass Mapping with Remotely Sensed Landscape Phenology. Ty C. Nietupski*[1], Becky K. Kerns[2]; [1]Oregon State University, Corvallis, OR, [2]US Forest Service - PNW Research Station, Corvallis, OR (400)

Paper withdrawn

Kochia (*Bassia scoparia*) Biology and Ecology Provide Insight into Optimal Management Scenarios. Charles M. Geddes*; Agriculture and Agri-Food Canada, Lethbridge, AB, Canada (401)

Kochia is the first known glyphosate-resistant (GR) weed species in western Canada. In 2011, the first confirmations of GR kochia in Canada were from chemical-fallow fields located in Warner County, Alberta. Baseline surveys conducted in 2012 (Alberta) and 2013 (Manitoba and Saskatchewan), identified glyphosate resistance in 5%, 5% and 1% of kochia populations in Alberta, Saskatchewan and Manitoba, respectively. More-recent surveys showed rapid spread of glyphosate resistance in this species after five years, with GR biotypes present in about 50% and 59% of kochia populations in Alberta (2017) and Manitoba (2018), respectively. Dicamba resistant biotypes were present in about 18% of kochia populations in Alberta in 2017, while 10% of kochia populations were triple-resistant to the herbicides tribenuron/thifensulfuron, glyphosate, and dicamba. Kochia is among the most problematic weed species in the southern Canadian prairies, and limited chemical options remain to control herbicide-resistant kochia postemergence within the main crops grown in these areas. The objective of this research was to use knowledge of kochia biology and ecology to develop species-specific management strategies to help control kochia in western Canada. Our preliminary field research suggests that crop rotations could be designed to compete effectively with herbicide-resistant kochia by integrating cultural weed management tools like narrow row spacing and increased seeding densities. In addition, the timing of harvest appears to be a key factor in limiting kochia seed production and the return of viable seed to the soil seedbank. This research builds on the concept of the critical period for weed control by shifting focus away from crop yield and embracing the concept of limiting weed seed returned to the soil seedbank; what could otherwise be referred to as the critical period for weed "seed" control. Albeit preliminary, results suggest that there may be an optimal time to cut kochia patches [around 2050 to 2200 GDD (Tbase = 0°C)] before the plants produce viable seed, and after which kochia regrowth is limited. This "critical period" may be manipulated through the use of pre-harvest or post-harvest herbicide and could be targeted by in-crop patch management or by growing crops which synchronize harvest timing with the critical period for weed "seed" control.

A Multi-state Examination of Weed Phenology and its Drivers. Lauren M. Lazaro*[1], Lovreet S. Shergill[2], Jeffrey Evans[3], Muthukumar V. Bagavathiannan[4], Mandy Bish[5], Jason A. Bond[6], Kevin W. Bradley[5], William S. Curran[7], Adam Davis[8], Wesley Everman[9], Michael L. Flessner[10], Nicholas Jordan[11], John Lindquist[12], Jason K. Norsworthy[13], Larry Steckel[14], Mark VanGessel[15], Steven B. Mirsky[16]; [1]Louisiana State University AgCenter, Baton Rouge, LA, [2]USDA-ARS & University of Delaware, Beltsville, MD, [3]Farmscape Analytics, Concord, NH, [4]Texas A&M University, College Station, TX, [5]University of Missouri, Columbia, MO, [6]Mississippi State University, Stoneville, MS, [7]Penn State University, University Park, PA, [8]University of Illinois, Urbana, IL, [9]North Carolina State University, Raleigh, NC, [10]Virginia Tech, Blacksburg, VA, [11]University of Minnesota, Saint Paul, MN, [12]University of Nebraska-Lincoln, Lincoln, NE, [13]University of Arkansas, Fayetteville, AR, [14]University of Tennessee, Jackson, TN, [15]University of Delaware, Georgetown, DE, [16]USDA-ARS, Beltsville, MD (402)

Multiple herbicide-resistant (MHR) weeds are challenging sustainable crop production as herbicides are rapidly becoming less effective and herbicide discovery has slowed. New integrated weed management (IWM) practices are urgently needed. One promising tactic for managing MHR weeds is Harvest Weed Seed Control (HWSC), in which weed seeds are removed/destroyed at harvest time to reduce the soil seedbank. The primary factor on which success of HWSC practice relies is the biological attribute of seed retention at crop maturity enabling its collection and processing at crop harvest. Thus, the objective of this study was to determine the amount of weed seed production that was shattered or retained on the plant at and after soybean (*Glycine max* L. Merr) physiological maturity and to determine which weed species were viable for harvest weed seed control (HWSC). A three-year trial was conducted across fourteen states, where twenty-five different species were observed (sixteen broadleaf and nine grass species). At the onset of inflorescence, four flats were placed underneath the targeted weeds and seed shatter was assessed weekly until one month after soybean maturity. At that time, the targeted weeds were collected to determine biomass and final seed retention. At soybean maturity, the targeted broadleaf species, in general, had retained 90% or greater of their seed. Furthermore, Palmer amaranth (*Amaranthus palmeri* S. Watson), smooth pigweed (*Amaranthus hybridus* L.), hemp sesbania (*Sesbania herbacea* (Mill.) McVaugh), common lambsquarters (*Chenopodium album* L), johnsongrass

(*Sorghum halepense* (L.) Pers.), and common cocklebur (*Xanthium strumarium* L.) retained greater than 90% of its seed until three weeks after soybean maturity. Other species, such as waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer), seed retention was variable across sites, with greater than 90% of its seed retained until two weeks after soybean maturity at 50% of the sites. Overall, broadleaf weeds retained more seeds overtime compared to the grass species and larger weeds overall retained more seeds than smaller weeds. In addition, weather patterns did not play a significant role in weed seed shatter across regions. Our research determines that soybean maturity and harvest dates are critical in weed seed shatter. Weeds must not be allowed to produce seed and must be controlled by soybean maturity to reduce the amount of weed seed that can enter the soil seedbank.

How is Dicamba Doing on Palmer Amaranth (*Amaranthus palmeri*) in the US Mid-South?
Nilda Roma-Burgos*[1], Matheus Machado Noguera[1], Larry Steckel[2], James W. Heiser[3], Taghi Bararpour[4], Robert L. Nichols[5]; [1]University of Arkansas, Fayetteville, AR, [2]University of Tennessee, Jackson, TN, [3]University of Missouri, Portageville, MO, [4]Mississippi State University, Stoneville, MS, [5]Cotton Incorporated, Cary, NC (403)

The commercialization of dicamba-tolerant crops (i.e., soybean) has enabled the application of dicamba over millions of acres. The rapid adoption of this technology is primarily driven by the need to find alternative chemical tools to manage multiple-resistant populations of Palmer amaranth (*Amaranthus palmeri*). This has initiated a widespread selection pressure on the weed, which could result in yet another resistance problem to evolve in a few years. Reports about fields with Palmer amaranth escaping dicamba applications are starting to arise. This study was conducted to determine if, indeed, some populations are starting to show the effect of this selection pressure. Palmer samples were collected between 2017 and 2019 from Arkansas, Mississippi, Missouri, and Tennessee. Thus far, 127 accessions have been tested with 0.56 kg ae/ha dicamba with up to 100 plants per accession. Dicamba was applied with nonionic surfactant in 187 L/ha spray volume to seedlings generally 7.6 – 10.2 cm tall. Plant response was evaluated visually 3 wk after treatment on a scale of 0 (no effect) to 100% (dead). Twenty-eight accessions (22%) were controlled 100%; the rest had survivors with an average injury of 35 – 90%. Considering the number of survivors and the level of injury of each survivor, the accessions that were not controlled 100% grouped into three clusters. Two of these clusters had 4% survivors, but differed in the level of injury with an average of 61% and 82%, respectively. The third group had 20% survivors with about 70% injury. The few F1 populations we had produced so far showed higher tolerance to dicamba compared to the original populations. Expression analysis of a few genes associated with resistance to auxinic herbicides did not show differential induction. It is likely that differential metabolism of dicamba occurs in tolerant plants. Resistance selection is occurring rapidly in some populations. Complete control is necessary.

Impact of Elevated Temperature, CO_2, and Soil Moisture Stress on Seed and Plant Morphological Traits of Italian Ryegrass (*Lolium multiflorum*). Aniruddha Maity*[1], Zorica Vasic[1], Victor Cieza[2], Gerald Ray Smith[3], Muthukumar V. Bagavathiannan[1]; [1]Texas A&M University, College Station, TX, [2]Department of Soil and Crop Sciences, Texas A&M University, College Station, TX, [3]Texas A&M University, Overton, TX (404)

Given the anticipated changes to future climatic conditions, the effects of various climatic stressors on plant vegetative and reproductive traits have been studied in a large number of crop species. However, weed species infesting different cropping systems didn't receive similar levels of attention, though weeds interfere and compete with crops for critical resources and ultimately impact yield and profits. In wheat production, Italian ryegrass (*Lolium multiflorum*) is an important weed species in the United States and several other countries. Published literature is available on the impacts of elevated temperature, CO_2, and soil moisture stresses on wheat growth, but the impacts on Italian ryegrass has not been investigated in depth. In this study, we examined the effect of two temperature regimes, 30°/25°C and 25°/20°C day/night; two CO_2 levels, 700ppm and 400ppm; and two levels of soil moisture, 100% and 25% field capacities in controlled environment growth chambers on seed and plant morphological traits of six Italian ryegrass accessions collected from Texas Balcklands. Results indicated that temperature alone showed significant effects ($p<0.01$) on plant height, leaf number, length of flag leaf and flag leaf sheath, and also on yield attributing traits such as the number of reproductive tillers, spikes, and spikelets, and seed filling (%), whereas CO_2 and soil moisture alone only impacted plant height, flag leaf sheath length, and seed filling (%). Significant interactions were observed among the stressors which varied across the traits. Overall, temperature*CO_2 interaction was the most impactful factor, which influenced reproductive traits more so than the vegetative traits measured. Seed shattering (%) varied significantly ($p<0.01$) for temperature and CO_2 but not for other stressors, whereas seed dormancy (%) significantly responded ($p<0.01$) to all the stressors studied. Findings are useful in understanding likely changes to ryegrass population dynamics associated with future climate change scenarios.

The Effects of Desiccation on Broad-leaved Dock (*Rumex obtusifolius*) and Curled Dock (*Rumex crispus*) Root Fragment Regeneration. Khalid S. Alshallash*; Shaqra University / Saudi Arabia, Riyadh, Saudi Arabia (405)

Fresh root fragments of *R. crispus* and *R. obtusifolius* which contain 65-70 % moisture initially, progressively lose moisture when desiccated under conditions matching summer weather in south-east England. The likelihood of shoot emergence and the time it took in glasshouse conditions were both affected by desiccation, with *R. crispus* most affected up to 48 hours and *R. obtusifolius* slower to emerge after 48 hours. These effects converged after longer desiccation periods, *R. crispus* entirely failed to emerge after 120 hours. Dry weight of emerged shoots was not significantly different between the species, until desiccated for 96 hours, when *R. obtusifolius* dry weight was significantly reduced. In outdoor trials, desiccation for 24 or 48 hours had less effect on emergence in either species when fragments were planted at the soil surface or at up to 10 cm of depth, compared to deeper plantings, but emergence was significantly lower from plantings at 15 or 20 cm. Emergence delays were not significantly different between the species, until planted at 15 or 20 cm, when *R. obtusifolius* was slower to emerge than *R. crispus,* an effect exacerbated by increasing desiccation. Similar interactions of increasing soil depth and desiccation were found in reductions in dry weight, number of tillers and leaf area, with *R obtusifolius* generally, but not exclusively, better able to withstand more extreme trial conditions. Our findings suggest that control of these highly troublesome weeds can be assisted by appropriate agricultural practices, notably exposing cut fragments to drying conditions followed by deep burial.

Ethical Considerations for Predicting Future Distribution of Weeds. Bruce Maxwell*; Montana State University, Bozeman, MT (406)

Scientists are increasingly dependent on models to project future outcomes. Weed Scientists are often asked to project which weeds will become a problem and what their distribution is likely to be in the future. Accurate forecasting of spatial extent, rate of spread and future distribution of weeds offers significant management advantages. Predicting the extent of weed distribution driven by climate change relies on linking climate change model projections with plant climate envelope models, plant physiological process models or empirical based probability of occurrence models. The point of this paper is to examine the multiple uncertainties introduced into conclusions from linking complex models and to introduce the ethical considerations when performing this type of analysis. In addition, potential mechanisms to maximize objectivity in assessments involving linked models were suggested. For example, ensemble of models are often used following the accepted logic in climate model projections. A case study where climate models were linked with a range of species distribution models to project weed distributions across the state of Montana by two different labs demonstrated a range of ethical issues.

A Model for Simulating Crop-Weed Competition for Light, Soil Water and Nitrogen. John Lindquist*[1], Lammert Bastiaans[2], Xinyou Yin[2]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]Wageningen University and Research, Wageningen, Netherlands (407)

Weeds cause crop yield loss indirectly through their influence on the resources required for crop growth. The outcome of crop-weed competition is driven by the physiological mechanisms that regulate the effect of each species on a given resource, and their response to the quantity of that resource available to the plant. Our long-term goal is to use quantitative information on resource uptake and utilization within ecophysiological models of interplant competition to predict the outcome of crop-weed interactions as influenced by resources in a changing climate. A simulation model for interplant competition was modified to include competition for soil water and nitrogen (N). Little published information is available on crop and weed response to soil resource supply. This information is critical if we wish to understand the importance of weeds in causing crop loss under future climate change scenarios where the frequency and quantity of rainfall may vary greatly in many agricultural regions worldwide. Predicting the outcome of interplant competition for soil water and N requires accurate prediction of soil water and N supply, their demand by each species, and the efficiency with which each is used within the plant. Competition for soil resources involves direct and indirect processes because they can be stored in soil. We outline approaches to simulate soil resource supply, demand of a mixed canopy, and the effects of resource deficit on plant growth. Research on maize and velvetleaf (*Abutilon theophrasti*) in response to varying soil water and N in Nebraska will be used as examples of quantifying plant response to available soil resource supply. Gaps in the existing literature on crop-weed competition for soil resources will be highlighted and research needs prioritized.

Climate-Mediated Weed Species Composition Shifts in a Rainfed Corn System. Erin E. Burns*; Michigan State University, East Lansing, MI (408)

Nearly all crop production is impacted by drought. Significant corn yield losses can occur during years when in-season rainfall is limited during pollination and grain fill. Future climate scenarios for the Great Lakes Region predict more precipitation in heavy rainfall events, leaving more days during the growing season that have little or no precipitation, polarizing the wet and dry periods. To address this future climate scenario a field study was conducted in East Lansing, MI in 2018-2019 evaluating the impacts of reduced precipitation and weed competition on drought and non-drought tolerant corn hybrid performance. The study was conducted as a split-plot randomized block design with four replications. Whole plots were assigned to a corn hybrid with and without the Genuity® DroughtGard® trait. Sub-plots were factorial combinations of one of three weed densities (weed-free, 50% weeds, 100% weeds) and presence or absence of precipitation. Rainout shelters were designed to impose 70% rainfall interception. Weed density by species was measured three times during the season. Weed biomass by species was collected at the end of the season. Dominant weed species in 2018 included: common lambsquarters (*Chenopodium album*), Powell amaranth (*Amaranthus powellii*), velvetleaf (*Abutilon theophrasti*), and green foxtail (*Setaria viridis*). Dominant weed species in 2019 included: green foxtail (*Setaria viridis*), common lambsquarters (*Chenopodium album*), horseweed (*Conyza canadensis*), and common purslane (*Portulaca oleracea*). In 2018, weed density was not impacted by precipitation level or corn hybrid. In 2019, weed density was not impacted by corn hybrid. However, weed density was lower under reduced precipitation than under ambient precipitation (p=0.003). Furthermore, in 2018 and 2019 weed communities under reduced precipitation were more diverse than weed communities under ambient precipitation (p=0.099). Additionally, species evenness was found to be more uniform under reduced precipitation (p=0.001). Overall, results highlight water stress modifies weed community composition and density in a rainfed corn system.

Development of a Novel Derived Polymorphic Amplified Cleaved Sequence (dPACS) Assay for the Identification of the Resistance-Causing D210 PPO Codon Deletion in Amaranthus and Ambrosia Species. Shiv S. Kaundun*, Sarah-Jane Hutchings, Elisabetta Marchegiani, Ruben Rauser, Lucy V. Jackson; Syngenta, Bracknell, United Kingdom (409)

Resistance to protoporphyrinogen oxidase (PPO)-inhibiting herbicides in *Amaranthus rudis/palmeri* from corn/soybean production systems in the USA appears to be mainly due to a codon deletion at position 210 of the target *PPX2L* gene. In this study, we have developed a simple and cost-effective derived Polymorphic Amplified Cleaved Sequenced (dPACS) marker for detecting this resistance-causing deletion in *A. rudis* and other relevant weed species. Ninety-six plants from 16 diverse fomesafen-sensitive and resistant *A. rudis* populations from Illinois and Iowa were used to establish the dPACS procedure. The assay requires forced mismatches in both the forward and reverse PCR primers and employs the restriction enzyme *Xcm*I for the positive identification of wild type glycine residue at *PPX2L* codon position 210. The data from the dPACS method, using either leaf tissues or seeds as starting material, were completely correlated with direct Sanger sequencing results for samples that gave readable nucleotide peaks around codon 210 of *PPX2L*. Furthermore, the assay was directly transferable to all four other *Amaranthus* species tested, and to *Ambrosia artemisiifolia* using species-specific primers. The proposed assay will allow the rapid detection of the ?210 codon deletion in the *PPX2L* gene and the timely development of management strategies for tackling growing resistance to PPO-inhibiting herbicides in *A. rudis* and other broadleaf weed species.

An *IAA16* Mutation Endowing Dicamba Resistance in Kochia (*Bassia scoparia*) Also Alters Plant Architecture, Vegetative and Reproductive Development, and Reduces Plant Competitiveness. Chenxi Wu*[1], Marta Paciorek[1], Sherry LeClere[1], Kang Liu[1], Alejandro Perez-Jones[2], Philip Westra[3], Doug Sammons[4]; [1]Bayer CropScience, St Louis, MO, [2]Bayer Crop Science, Chesterfield, MO, [3]Colorado State University, Fort Collins, CO, [4]Sammons BFC LLC, St Louis, MO (410)

The orchestrating role of a synthetic auxins resistance endowing mutation at *IAA16* (G73N) in plant growth and defense, was investigated in *Bassia scoparia*. Different G73N genotypes from a segregating resistant parental line (9425) were characterized for cross resistance to dicamba, 2,4-D and fluroxypyr, stem and leaf morphological changes, and floral/seed development. Plant competitiveness and dominance of the fitness effect was quantified through glasshouse replacement series studies on F_2 lines. 9425 mutant plants were 1) 30-50% shorter with a more tumbling style plant architecture; 2) had thicker and more ovate (versus lanceolate and linear) leaf blades with lower photosynthesis efficiency, and 40-60% smaller stems with less developed vascular bundle systems; 3) flowered 2-7 days earlier, and exhibited 60-70% decrease in herkogamy as well as reduced dichogamy, promoting self-pollination that maximizes seed production; 4) had 16-60% higher reproductive allocation, producing similar amount of "winged" seeds with 30-70% longer sepals. F_2 mutant plants were significantly less competitive and produced much less biomass and seeds under competition. The fitness effect of the G73N mutation was mostly semi-dominant (0.5) and fluctuated with the environments. Kochia was able to ameliorate the deleterious effects of G73N through higher reproductive allocation, and co-evolution of more efficient reproductive mechanisms: 1) altered reproductive development and mating strategies for reproductive assurance; 2) more effective long-distance seed dispersal mechanisms to facilitate the spread of resistance. A hypothetical model is proposed, which correlates herbicide resistance to the evolutionary trajectory of plant adaptation to abiotic stress.

Common Sowthistle (*Sonchus oleraceus*) and Prickly Lettuce (*Lactuca serriola*) in Lentil (Lens culinaris) Crops of Southern Australia: Managing Herbicide Resistance and Highly Mobile Resistance Genes. Alicia B. Merriam*[1], Jenna Malone[1], Gurjeet S. Gill[1], Christopher Preston[2]; [1]University of Adelaide, Adelaide, Australia, [2]University of Adelaide, Glen Osmond, Australia (411)

In southern Australia, the broadleaf weeds common sowthistle and prickly lettuce have become more common in annual cropping systems following the uptake of reduced tillage. Both species have widespread resistance to the ALS inhibiting herbicides and seed highly adapted to wind dispersal. They are particularly problematic in lentil crops due to poor crop competition and a lack of post emergent herbicide options. Best practice relies on controlling weeds prior to sowing or crop emergence and growing a cereal crop prior to a pulse can help reduce broadleaf weed burden for the following crop. This research aimed to establish whether management within a cereal phase had a measurable effect on weed density in the following growing season, despite seed mobility. Two-year field trials were established at two sites in lentil-producing areas of South Australia. Levels of crop seeding density and herbicide treatments applied in factorial arrangement in a wheat crop and weed densities were assessed early in the following season. Populations of both species were also sampled from each site and screened for resistance to the ALS inhibitors, 2,4-D and glyphosate. Crop competition treatments had no significant effect on weed density at either site in year 1 or year 2. A carryover effect of herbicide treatment was only significant on common sowthistle density at one of the sites, where initial weed density was the highest. High weed densities were found in year 2 even where weeds were absent or very sparse following herbicide treatment in year 1, indicating that colonization from outside the study area can make a significant contribution to weed numbers.

Unequal Crossover in Heterochromatin Rich Region of a Chromosome Drives Amplification of ACC-ase Gene and Sethoxydim Resistance in Large Crabgrass. Mithila Jugulam*[1], Dal-Hoe Koo[1], Sushila Chaudhari[1], Martin Laforest[2], Brahim Soufiane[2], Bernd Friebe[1], Bikram S. Gill[1]; [1]Kansas State University, Manhattan, KS, [2]AAC-AAFC, St-jean-sur-richelieu, QC, Canada (596)

Acteyl-CoA carboxylase (ACCase)-inhibitors are used for selective control of grass weeds in agriculture. Extensive use of these herbicides resulted in the evolution of a high level of resistance to sethoxydim (also found cross resistant to other ACCase-inhibitors) in a large crabgrass population in Ontario, Canada. Plants have two nuclear encoded isoforms of ACCase gene, i.e., plastidic and cytoplasmic. The plastidic isoform is homomeric in monocots, while heteromeric in other plants. The homomeric form is sensitive to ACCase-inhibitors. Previous research reported a 5-7-fold increase in *ACCase* gene copies with a 4-9 fold increase in transcript expression in ACCase-inhibitor-resistant (R) large crabgrass biotypes relative to a sensitive (S) biotype. In this research, we investigated the mechanism of amplification of the *ACCase* gene using molecular cytogenetics techniques. We analyzed the genomic organization of the amplified copies using fluorescent *in situ* hybridization (FISH) on chromosomes of R and S biotypes. Mitotic metaphase chromosome (diploid: 2n=36) spreads were prepared from the root tips of two R biotypes, which had 4 and 7 and a S biotype with 1 copy of the ACCase gene. Using ~ a 7 kb ACCase gene sequence, a fluorescent-labeled probe was prepared for a single copy FISH analysis. FISH in S biotype displayed faint signals on two pairs of homologous chromosomes confirming the two isoforms of *ACCase* genes in large crabgrass. FISH analysis in R biotypes with 4 and 7 *ACCase* copies, showed brighter signals on only one pair of homologous chromosomes, while the other pair had faint hybridization signals, similar to S biotype. Importantly, the amplification of the *ACCase* gene was found on heterochromatin rich regions near telomere, but not in pericentromeric region where recombination is known to be suppressed. These results indicate a possible role of unequal crossover in the amplification of the homomorphic plastidic isoform of *ACCase* gene, the target of sethoxydim in large crabgrass. Gene duplication help create genetic diversity in organisms, which is crucial for the selection of traits for adaptive advantage. Here in large crabgrass, under intense selection pressure, adaptive amplification following gene duplication resulted in the evolution of resistance to ACCase-inhibitors.

A Novel Invasive Annual Grass in North American Interior Ecosystems: *Ventenata dubia* (North Africa Grass). Becky K. Kerns*[1], Claire Tortorelli[2], Ty C. Nietupski[2], Michelle A. Day[3], Meg Krawchuk[2], Bridgett Naylor[4], John Kim[1]; [1]US Forest Service - PNW Research Station, Corvallis, OR, [2]Oregon State University, Corvallis, OR, [3]US Forest Service - Rocky Mountain Research Station, Corvallis, OR, [4]US Forest Service - PNW Research Station, La Grande, OR (597)

Ventenata dubia (ventenata) is a relatively new invader in the Inland Northwest of the US. It has invaded similar aridlands as other exotic annual grasses, but also threatens a wider range of ecosystems. We recently launched a series of studies to examine how the ventenata invasion is transforming the Blue Mountain Ecoregion (BME) in eastern Oregon now and in the future. We have recorded ventenata from elevations of 392 to 1808 m, in plant community types ranging from forests and meadows to woodlands and shrublands. We used spatiotemporal satellite image fusion methods to estimate the species' unique landscape phenology and have estimated the present extent across the BME. Our studies indicate that 1) areas with ventenata cover >20% are extensive across the ecoregion, 2) communities historically resistant to exotic annual grasses are susceptible to invasion, and 3) invasion is not necessarily catalyzed by disturbance, however wildfire may exacerbate impacts on species richness, evenness, and functional diversity. Ventenata has substantially expanded the overall annual grass invasion footprint and associated impacts in the interior west. Recognizing how the ventenata invasion extent, drivers and impacts differ from other annual grass invasions may provide insight into mechanisms of community invasibility, grass-fire feedbacks, and aid the development of species-specific management plans. Future work is planned to simulate how fuels, fire regimes, and fire effects are shifting across the region now and into the future.

Efficacy of Crop Rotation, Tillage and Herbicide for Long-Term Herbicide-Resistant Kochia (*Bassia scoparia*) Management. Elizabeth G. Mosqueda*[1], Andrew R. Kniss[2], Nevin Lawrence[3], Prashant Jha[4], Charlemagne A. Lim[5]; [1]California State University-Monterey Bay, Marina, CA, [2]University of Wyoming, Laramie, WY, [3]University of Nebraska-Lincoln, Scottsbluff, NE, [4]Iowa State University, Ames, IA, [5]Montana State University, Huntley, MT (598)

Few field studies quantify the combined impacts of diverse herbicide-resistant weed management practices on the evolution of herbicide resistance. Kochia (*Bassia scoparia*) is problematic for growers throughout the Western United States, in part, because of evolved resistance to numerous herbicides. Field studies were conducted from 2014 through 2017 at sites in Wyoming, Montana, and Nebraska to quantify the combined impacts of crop rotation, tillage, and herbicide use on the evolution of ALS-resistant kochia. A known proportion of ALS-resistant kochia was established in 2014 before imposition of treatments. Tillage (main-plot) included annual intensive tillage or minimum tillage. Crop rotations (split-plot) consisted of continuous corn, corn-sugarbeet, corn-dry bean-sugarbeet, and corn-dry bean-small grain-sugarbeet. Herbicide treatments (split-split-plot) included complete reliance on ALS inhibitor herbicides, mixtures including ALS inhibitors, or an annual rotation which included ALS herbicides. Kochia densities, seed production per plant, and seed production per unit area were estimated each summer. Data was analyzed using a linear mixed effects model for each of the four years the study was conducted. Two and three-way interactions between main effects were not statistically significant (P-values >0.1) except for kochia seed production per plant in 2014 (P-value <0.001). Kochia density and seed production per unit area were lowest in intensively tilled, four crop rotation, and ALS mixture treatments by the final year of the study. Kochia seed production per plant was lowest in four crop rotation and ALS mixture treatments. Tillage treatments did not impact kochia seed production per plant any year of the study.

Population Genomics of Italian Ryegrass (*Lolium perenne* L. spp. *multiflorum*) with Diverse Herbicide Resistance Patterns: a RAD-Seq Approach. Caio A. Brunharo*, Andrew G. Hulting; Oregon State University, Corvallis, OR (599)

Italian ryegrass populations exhibiting a variety of herbicide resistance patters were recently identified in Oregon across the Willamette Valley. Because of the outcross, wind-pollinating breeding system of ryegrass species (including interbreeding between perennial and annual ryegrass), the genetic background of the resistant populations is largely unknown. The objective of this research was to characterize population genetics estimates between herbicide resistant and susceptible Italian ryegrass populations. We employed a restriction site-associated DNA sequencing approach to identify genetic single nucleotide polymorphisms (SNPs) across the Italian ryegrass genome. DNA was extracted from 15-16 individuals from each of 17 Italian ryegrass populations, in addition to an outgroup and a known perennial ryegrass populations, followed by restriction enzyme digestion with ApeKI. Digested samples were multiplexed (96 per sequencing run) and analyzed in three lanes of an Illumina HiSeq3000 platform. SNP's were identified *de novo* using Stacks (v.2.5), and assembled contigs were aligned to a draft perennial ryegrass genome. After stringent SNP filtering step, principal component analysis, discriminant analysis of principal component, STRUCTURE, pairwise F_{st}, and F_{is} were assessed. Results suggest that herbicide resistant Italian ryegrass populations are distant related to perennial ryegrass, as indicated by principal component analysis, where herbicide resistant populations seem to share the majority of the markers among them compared to the susceptible populations. Bayesian clustering with STRUCTURE identified the presence of nine clusters. F_{st} analysis supported multidimensional analysis in regards to sub-structuring of Italian ryegrass populations. Future studies will focus on Fst outlier analysis and environmental association analysis to identify the genetic basis of herbicide resistance.

Herbicide Resistance Survey in Winter Wheat Cropping Systems Identifies the First *Secale cereale* Imazamox-Resistant Population. Neeta Soni*, Eric P. Westra, Philip Westra, Todd A. Gaines; Colorado State University, Fort Collins, CO (600)

Early detection of herbicide resistance in weeds is crucial for the successful implementation of integrated weed management. Feral rye (*Secale cereale*), downy brome (*Bromus tectorum*), and jointed goatgrass (*Aegilops cylindrica*) are problematic winter annual grasses in Colorado. Post-emergence control of winter annual grasses in wheat is limited to imazamox (Clearfield® wheat) and quizalofop (CoAXium® wheat). Currently, there is no information on the imazamox and quizalofop resistance status for feral rye, downy brome, and jointed goatgrass in Colorado. Our main objectives were to conduct an imazamox and quizalofop resistance survey for feral rye, downy brome, and jointed goatgrass and to identify the molecular mechanisms from the selected resistant biotypes. Greenhouse herbicide screening was conducted using labeled rates of imazamox and quizalofop to evaluate 270 collection sites across the three weed species. No resistance to imazamox or to quizalofop was identified in any downy brome or jointed goatgrass samples. No feral rye samples were resistant to quizalofop. Two feral rye populations (named A and B) were identified with resistance to imazamox. Acetolactate synthase (ALS) gene sequencing and *in-vitro* enzyme assays showed the known Ser653Asp mutation in population B conferring target-site resistance to imazamox, while population A had no ALS mutations and sensitive ALS enzyme, suggesting a non-target site mechanism. Enhanced metabolism was investigated by conducting an imazamox dose response with and without malathion as a cytochrome P450 inhibitor. Additionally, a metabolomics approach was used to quantify differences among intact imazamox and metabolites from susceptible and resistant feral rye individuals. Dose response results for population A showed a biomass reduction of 2.7-fold when imazamox at 52.5 g ai ha^{-1} was mixed with malathion compared to imazamox alone. Metabolism data showed a T50 (time for 50% degradation of intact imazamox) of 2.5 days for population A, whereas the susceptible control had a T50 of 5.9 days. This is the first report of both target-site and metabolism-based imazamox resistance in feral rye.

Weed Biology Insights to Improve Management of *Chloris virgata*. Bhagirath S. Chauhan*; University of Queensland, Gatton, Australia (601)

Abstract not available

Maternal Water Stress Influences Progeny Characteristics and Management in Palmer Amaranth. O. Adewale Osipitan*[1], Maor Matzrafi[2], Sara Ohadi[1], Mohsen B. Mesgaran[1]; [1]University of California, Davis, Davis, CA, [2]Newe Ya'ar Research Center, Department of Weed Research and Plant Pathology, Agricultural Research Organization, Ramat Yishai, Israel (602)

Often time we evaluate the immediate impact of prevailing environmental conditions on the growth and management of weeds, while the transgenerational impacts are rarely considered. It has been suggested that parental plants subjected to stress may result in progenies with increased stress tolerance. In this study, Palmer amaranth (*Amaranthus palmeri* S. Watson) plants from Kansas and California were used to test this hypothesis. We evaluated the influence of water stress (30% of well-watered condition) during the growth of parental plants on progeny seed characteristics, seedling emergence pattern, phenology, and response to herbicide control. Result showed that water stressed parental plants produced fewer but larger seeds, compare to the well-watered plants. The progeny from the water stressed parents had greater seed germination rate and percentage. The base water potential below which germination cannot occur, was lower for seeds from water stressed parents; suggesting that the progeny seeds are more water stress tolerant and can germinate from drier soils. Herbicide dose response study showed that progeny plants from water stressed parents, required increased amount of S-metolachlor, rimsulfuron and simazine to achieve 50% control. Our study suggests that a water stressed Palmer amaranth produced progenies that are more water tolerant with faster seedling emergence which could be a competitive advantage, and may require increased amount of herbicide inputs for control.

Salt Stress and Recurrent Herbicide Application May Speed the Evolution of Jungle Rice Resistant to Imidazolinones. Lariza Benedetti[1], Nilda Roma-Burgos[2], Luis A. Avila*[1], Gustavo M. Souza[1]; [1]Universidade Federal de Pelotas, Pelotas, Brazil, [2]University of Arkansas, Fayetteville, AR (603)

Salt Stress and Recurrent Herbicide Application May Speed the Evolution of Junglerice Resistance to Imidazolinone HerbicidesLariza Benedetti[1], Luis Antonio de Avila[1], Edinalvo Rabaioli Camargo[1], Anderson da Rosa Feijó[1], Marcus Vinicius Fipke[1], Nilda Roma-Burgos[21]Federal University of Pelotas; Crop Protection Graduate Program; Pelotas, RS, Brazil[2]University of

Arkansas; Crop, Soil and Environmental Sciences; Fayetteville, AR, USA *Echinochloa colona* (junglerice) presents an increasing challenge to rice production systems because of its ability to adapt to abiotic stresses such as salinity and herbicides. The recurrent selection of junglerice exposed to herbicide stress and adverse environmental conditions may accelerate weed resistance evolution. The objectives of this research were to study the joint effect of salinity stress and recurrent selection with sublethal dose of imazapic+imazapyr on tolerance to imidazolinone herbicides. The experiment was conducted in the greenhouse, in 8-liter pots containing four plants per pot. The study consisted of three generations of junglerice (G0, G1, G2). G0 was the parent susceptible population; G1 and G2 were progenies of recurrent selection. To produce these generations, a factorial experiment was conducted in a completely randomized design with four replications. Factor A was the herbicide (imazapic+imazapyr at 0.125x the recommended dose and non-treated check). Factor B was salt stress (0 and 120 mM NaCl). This study was initiated with field-collected seeds, to produce G1 seeds. The G1 seeds were subjected to the same treatments to produce G2 seeds. Then G0, G1, and G2 plants were subjected to a herbicide dose-response assay at 0, 0.0625, 0.125, 0.25, 0.5 and 2.0x the recommended dose, with and without salt stress. At three weeks after herbicide application, junglerice control was evaluated visually per plant on a scale of 0% (no symptoms) to 100% (dead). Junglerice response to sublethal herbicide dose did not differ between salt stress treatments regardless of generation (G0 to G2). The sublethal dose of herbicide caused higher injury to salt-stressed G0 plants than those without salt stress. The ED_{50} of junglerice treated with imidazolinones and salt stress was 0.148x the recommended dose in G0 and increased to 0.229x in G2. This level of ED_{50} is still within the susceptible range, being below the recommended field dose of the herbicide. However, this indicates that the combination of salt stress and sublethal herbicide dose facilitates adaptation to herbicide stress. We hypothesize that continued exposure to these conditions will accelerate the evolution of junglerice resistance to imidazolinone herbicides. The same principle may be true to other herbicides.

Burial Depth and Flooding Effects on Emergence of Five California Weedy Rice (*Oryza sativa* f. *spontaneae* Rosh.) Accessions. Liberty B. Galvin*[1], Mohsen B. Mesgaran[1], Whitney Brim-DeForest[2], Kassim Al-Khatib[1]; [1]University of California, Davis, Davis, CA, [2]University of California Division of Agriculture and Natural Resources, Yuba City, CA (604)

Weedy rice (*Oryza sativa* f. *spontanea* Rosh) has recently become a significant pest in California rice production systems. Factors including the conspecific nature of weedy rice with cultivated rice as well as lack of registered herbicides available for weed control have encouraged research and development of ecologically focused management strategies for weedy rice. However, early season growth of weedy rice should be well understood to improve efficacy of any proposed strategy. To contribute to these efforts an experiment was conducted to determine the flooding and burial depths that encourage or inhibit soil and water emergence of weedy rice under semi-controlled conditions. Four flooding depths at 0, 5, 10, and 15 cm as well as four burial depths, 1.3, 2.5, 5, and 10 cm were applied to pre-germinated weedy rice accessions 1, 2, 3, 4, and 5 as well as 'M-206' rice (medium grain, median maturity) for comparison in a randomized complete block design. When possible, weedy rice emergence from the soil and water surfaces, respectively, were counted daily. Results revealed that there was no significant difference between weedy rice plants that emerged from the soil surface and water surface, regardless of burial or flooding depths.

Additionally, burial depth played the most significant role due to a lack of soil emergence from depths at or below 5 cm. Most weedy accessions planted at 1.3 cm burial depths had significantly more dry weight at the end of 21 days compared to M-206. The results from this experiment provide evidence for improving efforts aimed at reducing the prevalence of weedy rice in California.

Exposure to Dicamba Influences Sex-Ratio in Palmer Amaranth (*Amaranthus palmeri*). Debalin Sarangi*[1], Aniruddha Maity[2], Nithya K. Subramanian[2], Muthukumar V. Bagavathiannan[2]; [1]University of Wyoming, Powell, WY, [2]Texas A&M University, College Station, TX (605)

Palmer amaranth (*Amaranthus palmeri* S. Watson), a dioecious species, is considered the most problematic weed in row-crop production systems in the United States. Sex ratio in dioecious plants can impact seed production and overall population dynamics. Experiments were conducted in 2018 and 2019 at College Station, TX to evaluate the impact of low-dose exposure of Palmer amaranth to dicamba on (1) differential sensitivity of sex types, and (2) sex-ratio. Three field-collected Palmer amaranth populations [Texas High Plains (HP), Central Texas (CT), and Nebraska (NE)] tested to be susceptible to dicamba (> 90% injury at 0.5× label dose, where 1× = 560 g ae ha^{-1}) were selected for this experiment. Male Palmer amaranth plants showed up to 1.6 times greater sensitivity to a low-dose (0.125×) application of dicamba, compared to female plants based on visual injury symptoms. Further, following the exposure to low-dose dicamba, there was a significant shift in the sex ratio towards more female plants in the HP and NE populations, whereas no difference was observed in the CT population. Exposure to the low-dose of dicamba didn't affect the seed viability of Palmer amaranth compared to nontreated control. The F_1 progeny of the HP population also exhibited a shift towards more female plants, but this response was not evident in the progenies of CT and NE populations. Results show that exposure to dicamba stress can influence a shift in sex ratio in Palmer amaranth, but the response appears to be biotype dependent. Further, greater sensitivity of male Palmer amaranth plants to dicamba may influence long-term population dynamics.

High Trait Variations Within and Among the Transcontinental Populations of a Global Invader: *Anthemis cotula* L. (Mayweed Chamomile). Subodh Adhikari*[1], Ian Burke[2], Sanford Eigenbrode[1]; [1]University of Idaho, Moscow, ID, [2]Washington State University, Pullman, WA (606)

Globally, invasive species have caused serious ecological and economic impacts. Regionally in the Pacific Northwest (PNW) USA, agricultural landscapes are in transition to increased crop diversification, but they are potentially vulnerable to invasion and infestation of weeds such as *Anthemis cotula* (Mayweed chamomile), as new crops are either less competitive or lack compatible herbicides for the weed management. Knowledge on functional traits of locally adapted populations help for early detection and site-specific management. Studies with other weed species have reported phenotypic traits directly linked to the plant's invasiveness, but we lack this information for *A. cotula*. In a common greenhouse experiment (n = 370 pots) conducted in 2019, we seeded 19 *A. cotula* populations from its two invading regions: The PNW, USA and Kashmir Himalaya, India. We measured traits of adaptive significance including phenology (e.g., flowering duration), growth (e.g., plant biomass), reproductive fitness (e.g., flower heads), and physiology [floral scent volatile organic compounds (VOCs)] on each plant and the data were analyzed using mixed-effects models for the effects of population on each trait. We observed a relatively high inter-and intra-population variation in most of the traits measured. Germination rates of Indian populations were > 50 % within 30 days of cultivation, while germination of some PNW populations remained ~ 2% during that period. Individuals from an Idaho site, Kambitsch Farm flowered for ~3 mo, while individuals from a Washington site, St. John, flowered for ~ 2 mo, although the number of flower heads per plant were similar for the two populations. Variation in these traits suggests adaptation to local site conditions. For example, the shorter flowering time for St. John may be adaptive in this site, which is drier and hotter than Kambitsch, giving advantage to producing flowers for a shorter time when water is available. We found differences in VOCs among and within populations. Floral VOCs may be associated with the invasiveness of plants by mediating the disruption of existing ecological networks and forming novel interactions with native pollinators possibly by attracting pollinators away from the native plants. Strong but more localized (i.e., at field scale) selection pressure of farm management practices (e.g., herbicide applications) in crop fields could have selected for herbicide resistance in some *A. cotula* populations. This would impart an advantage against competitors that lack herbicide resistance in these settings. The implications for long term management of *A. cotula* in the PNW and elsewhere will be discussed.

Impacts of Drought and Native Grass Competition on Buffelgrass (*Pennisetum ciliare*): Opportunities for Active Restoration. Hannah Lucia Farrell*, Elise S. Gornish; University of Arizona, Tucson, AZ (607)

Buffelgrass *(Pennisetum ciliare)* is a drought tolerant perennial bunchgrass that is invasive in dryland ecosystems throughout the world. There is little reported data showing successful long-term buffelgrass eradication followed by native plant establishment using popular methods such as herbicide application and manual removal. However, control efforts that use multiple treatment in tandem including seeding with native plants after treatment have been shown to be highly successful for reducing buffelgrass as well as aiding the recovery of native plant populations. In a greenhouse experiment, we studied which characteristics of plants were best at applying competitive pressure to buffelgrass seedlings, and thus would be most useful for restoring a site after buffelgrass treatment to prevent re-establishment. We measured plant height, shoot biomass, root biomass, flowers, and xylem water potential to understand how buffelgrass responds to growing with eight different native grass species. We also examined how drought might influence native species competition with buffelgrass. We found that, in drought conditions, fast growing, large grasses caused buffelgrass to bolt in size and become drought stressed. Conversely, in the presence of slow-growing drought-tolerant grasses, buffelgrass conserved size and water use. These results indicate that an appropriate seed mix to use after buffelgrass treatment would include both fast growing species that take up space quickly as well as highly drought tolerant species that develop their roots to survive periods of no water. Further, managers may want to consider selecting follow-up treatment methods based on the rain that season and the native species growing among the buffelgrass re-sprouts.

Structural Characterization of Phytotoxic Compounds from *Lantana camara*. Dr. Tauseef Anwar*, Huma Qureshi; Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan (608)

Four compounds viz. methyl oleate, methyl palmitate, methyl stearate and methyl linoleate, were characterized from the flowers of *Lantana camara* by combi*flash* chromatography followed by gas chromatography mass spectrometry as well as ^{1}H and ^{13}C nuclear magnetic resonance spectroscopic analyses. Bioassays showed that the four compounds had significant phytotoxic effects on the germination and seedling growth of weeds (*Avena fatua*, *Euphorbia helioscopia*, *Chenopodium album*, *Phalaris minor* and *Rumex dentatus*). Methyl palmitate being the most potent phytotoxic compound, inhibited growth parameters by approximately 80% at a concentration of 50µM. Methyl palmitate inhibited total chlorophyll and protein components of test species by 50-60 %. The results of activity testing indicated that the methyl palmitate had strong phytotoxic potential and cause different degrees of influence on growth of weeds.

WSSA SECTION 3: TURF AND ORNAMENTALS

Crew Specialty Herbicide (Dithiopyr + Isoxaben): A New Herbicide for Broad-Spectrum Weed Control in Turf and Ornamentals. David E. Hillger*[1], Amy L. Agi[2], Paul Marquardt[3]; [1]Corteva Agriscience, Thorntown, IN, [2]Corteva Agriscience, Brooks, GA, [3]Corteva Agriscience, Des Moines, IA (503)

Crew™ Specialty Herbicide is a new granular combination of dithiopyr + isoxaben (0.25% dithiopyr + 0.5% isoxaben) formulated onto the Verge granule. Application rates of Crew are 168-224 kg/ha in turfgrass and 168 kg/ha in landscape beds. Crew controls over 120 difficult weeds in turf and landscape beds including crabgrass, (*Digitaria spp.)*, annual bluegrass (*Poa annua*), henbit (*Lamium amplexicaule*), plantain (*Plantago spp.*), oxalis (*Oxalis spp.*), clover (*Trifolium spp.*), dandelion (*Taraxacum officinale*), chickweed (*Stellaria media*) and prostrate knotweed (*Polyonium aviculare*). Studies confirm that Crew is safe for use on cool-season turfgrass like bentgrass (*Agrostis stolonifera*), bluegrass (*Poa prantensis*), tall fescue (*Festuca arundinacea*), fine fescue (*Festuca spp.*) and ryegrass (*Lolium perenne*) as well as warm-season turfgrasses like bermudagrass (*Cynodon dactylon*), St. Augustinegrass (*Stenotaphrum secundatum*) and zoysiagrass (*Zoysia japonica*).

Moisture Status Affects Efficacy of Foramsulfuron for Postemergence Goosegrass (*Eleusine indica*) Control. James Brosnan*[1], Avat Shekoofa[2], Matthew T. Elmore[3], Jose J. Vargas[1], Dan Tuck[3], Greg Breeden[1], Joaquin Simon[2]; [1]University of Tennessee, Knoxville, TN, [2]University of Tennessee, Jackson, TN, [3]Rutgers University, New Brunswick, NJ (504)

Goosegrass (*Eleusine indica* L. Gaertn.) is a problematic summer annual weed of warm- and cool-season turfgrasses on golf courses, athletic fields, and lawns. Goosegrass is common in compacted soils following foot or vehicular traffic that reduces turfgrass cover. Although several herbicides are labeled for postemergence (POST) goosegrass control, eradication often requires multiple herbicide applications. We hypothesized that moisture status at application may affect efficacy of POST herbicides for goosegrass control in turf. Greenhouse research was conducted to evaluate the effect of soil moisture content on efficacy of five herbicides labeled for POST goosegrass control. Herbicides included carfentrazone-ethyl + 2,4-D-ester + mecoprop-p + dicamba (Speedzone; 28 + 857 + 269 + 78 g ha^{-1}, respectively), topramezone (24 g ha^{-1}), fenoxaprop (140 g ha^{-1}), foramsulfuron (44 g ha^{-1}) and thiencarbazone-methyl + foramsulfuron + halosulfuron-methyl (Tribute Total; 22 + 45 + 67 g ha^{-1}, respectively). Adjuvants were included with herbicides per label recommendations. These herbicides were applied to multi-tiller goosegrass plants (minimum of three tillers) maintained at three different volumetric soil moisture contents (VMC): < 12%, 12 to 20%, or > 20%. Non-treated controls were included at each VMC for comparison. Experimental design was a randomized complete block with six replications and the study was conducted during autumn 2018 in Knoxville, TN and repeated during summer 2019 in New Brunswick, NJ. Goosegrass control was visually assessed using a 0 (i.e., lowest) to 100% (i.e., highest) scale relative to non-treated controls at 36 days after treatment (DAT). Aboveground biomass for each treatment was quantified 44 DAT as well. At both locations, increased soil moisture at application enhanced efficacy of select herbicides for POST goosegrass control. When applied to plants maintained at >20% VMC in Tennessee, goosegrass control ranged from 48 to 98% compared to 10 to 24% following treatment to plants at < 12% VMC. In New Jersey, goosegrass control ranged from 23 to 88% when applied to plants at >20% VMC compared to only 10 to 41% when applied to plants at < 12% VMC. Improved goosegrass control under conditions of elevated VMC was most pronounced for fenoxaprop as well as herbicides containing acetolactate synthase inhibitors. Research was conducted during summer 2019 to explore the impact of high vapor pressure deficit (> 3 kPa) on foramsulfuron (44 g ha^{-1}) efficacy for goosegrass control. Vapor pressure deficit (VPD) was evaluated under two air temperatures (32 and 38 C) and two soil types (silt loam and sand). Additionally, studies were conducted to determine the effect of progressive soil drying (30 days) on efficacy of foramsulfuron (44 g ha^{-1}) for POST goosegrass control in silt-loam soil and sand. In all experiments, goosegrass plants were established from seed and allowed to mature for four weeks before beginning research. Foramsulfuron efficacy was greatest under conditions of high VPD and 38 C air temperature; treatment at 44 g ha^{-1}reduced goosegrass transpiration rate and leaf area compared to non-treated controls in the silt-loam environment. No statistically significant differences were detected among treated and non-treated plants in sand regardless of VPD or air temperature. In our progressive soil drying study, transpiration rates of treated plants dropped to 0.2 mmh^{-1} eight days after application of foramsulfuron to goosegrass plants growing in silt-loam. In sand, transpiration reductions to 0.2 mmh^{-1} occurred eighteen days later. Overall, this research showed the impact of environment and soil type on efficacy of herbicides for POST goosegrass control. For foramsulfuron specifically, we determined that the herbicide is more efficacious when applied to goosegrass when air is dry (> 3kPa VPD) and air temperature is increased. Soil with greater water holding capacity (i.e., silt-loam) helped with plant transpiration and possibly improved efficacy of foramsulfuron for POST goosegrass control.

Efficacy of Pinoxaden for Grass Control. Jeffrey Derr*; Virginia Tech, Virginia Beach, VA (505)

Postemergence grass control is an important concern in turfgrass, especially in bermudagrass (*Cynodon* spp.), where there are limited options for control. Dallisgrass (*Paspalum dilatatum* Poir.) control is especially problematic as there are few options for control and repeat applications are required. There are limited options for smooth crabgrass *[Digitaria ischaemum* (Schreb.) Schreib. ex Muhl] and coastal (field) sandbur (*Cenchrus spinifex* Cav.) control. Pinoxaden is a newly-developed postemergence herbicide for use in bermudagrass and certain other warm-season turf species. Pinoxaden is an ACCase inhibitor that can be applied at broadcast rates of 0.035 or 0.07 kg ai/ha. Spot treatments can be made once or twice at 0.14 kg ai/ha. Pinoxaden was applied at the broadcast rates in two studies and at the spot-treatment rate in three studies. For all pinoxaden treatments, Agridor adjuvant was added at 0.5% v/v. Pinoxaden applied once at 0.07 kg/ha or twice at 0.035 kg/ha did not control smooth crabgrass or dallisgrass. When applied once at the spot treatment rate of 0.14 kg/ha, pinoxaden provided excellent control of smooth crabgrass and coastal sandbur and two applications at 014 kg/ha gave excellent dallisgrass control. Pinoxaden only caused slight temporary injury to bermudagrass. When applied at the spot-treatment rate, pinoxaden is an effective postemergence herbicide for key grassy weeds in bermudagrass turf.

Frequent, Low-Dose Treatments for Weed Control on Putting Greens. John M. Peppers*, John Brewer, Shawn Askew; Virginia Tech, Blacksburg, VA (506)

In the transition zone, crabgrass and goosegrass are problematic weeds, especially on creeping bentgrass greens experiencing biotic or abiotic stress. Creeping bentgrass maintained at greens height is typically more sensitive to herbicides. Currently, there are no postemergence herbicides registered to control crabgrass or goosegrass on creeping bentgrass greens. Experimental results have shown that fenoxaprop can be applied at low doses weekly or biweekly on greens to control young weed seedlings as they emerge. Our objective was to evaluate this frequent-treatment, low-dose approach with fenoxaprop, topramezone, quinclorac, and siduron for crabgrass and goosegrass control, as well as creeping bentgrass response. Both quinclorac applied weekly and biweekly at 140 and 280 g ai/ha, respectively, and fenoxaprop applied weekly and biweekly at 17 and 35 g ai/ha, respectively, injured creeping bentgrass 30 to 60% at 52 days after initial treatment. Siduron at 5.6 or 13 kg ai/ha applied weekly or biweekly, respectively, did not injure creeping bentgrass and topramezone applied at 1.5 to 6.1 g ai/ha caused transient injury that never exceeded 15%. Fenoxaprop controlled both crabgrass and goosegrass while quinclorac controlled only crabgrass. Siduron completely controlled crabgrass but controlled goosegrass approximately 50% by the end of the season. Topramezone completely controlled goosegrass but controlled smooth crabgrass approximately 60% by the end of the season. Due to the higher price of siduron relative to other treatments, additional studies were conducted to evaluate lower rates of siduron for smooth crabgrass control. In these studies, siduron completely controlled smooth crabgrass (>95%) when applied biweekly at four rates between 3.3 and 13 kg ai/ha. By reducing the siduron rate from 13 kg ai/ha to 3.3 kg ai/ha, a golf course, with four acres of putting greens, could reduce potential economic burden from $13,335/yr to $3,150/yr. Siduron is currently the only herbicide included in these studies that is registered for use on golf greens. These data suggest siduron, even at reduced rates, is a safe option for season-long control of crabgrass and suppression of goosegrass.

Mitigating Creeping Bentgrass Phytotoxicity from Topramezone. Clebson G. Goncalves*[1], John Brewer[1], Joseph S. McElroy[2], Shawn Askew[1]; [1]Virginia Tech, Blacksburg, VA, [2]Auburn University, Auburn, AL (507)

Recently, the HPPD-inhibiting herbicide, topramezone's efficacy and safety has been the focus of turfgrass research. Previous research has found creeping bentgrass tolerance to topramezone can be influenced by different factors such as application rates, tank mixtures, growing season, soil/air temperature, precipitation, and other environmental conditions. Recent research at Auburn University and Virginia Tech has shown that applying topramezone at lower rates and earlier in the season can potentially reduce creeping bentgrass injury. Further studies have recently shown that tank mixtures of topramezone with additive products can reduce bleaching and allows for lower topramezone use rates while maintaining crabgrass and goosegrass control. The objectives of this research were to evaluate potential safening of topramezone via combination with paclobutrazol, Fe chelate or a turfgrass pigment in Alabama and Virginia. Greenhouse treatments for experiment 1 included topramezone applied alone (20.8 g ai ha^{-1}), in tank mixture, three days before or three days after: paclobutrazol (98.1 g ai ha^{-1}), Fe chelate (610.3 g ai ha^{-1}) or turfgrass pigment (1.68 kg ha^{-1}) applications. For experiment 2, treatments included topramezone applied at two rates (5.2 or 10.4 g ai ha^{-1}), alone and in a tank mixture with paclobutrazol were made. Field treatments included three sequential applications of topramazone (5.2 or 10.4 g ai ha^{-1}) alone and in combination with paclobutrazol (98.1 g ai ha^{-1}), Fe chelate (610.3 g ai ha^{-1}), or turfgrass pigment (1.68 kg ha^{-1}). Greenhouse experiment showed that tank mixtures of topramezone and paclobutrazol or topramezone applied three days after paclobutrazol application showed less F_v/F_m reduction compared to topramezone alone. For the field experiment, most topramezone rates evaluated were less injurious in 2019 than in 2018. In 2018, topramezone alone injured creeping bentgrass similarly or more compared to tank-mix combination with paclobutrazol, Fe chelate, or turfgrass pigment after one, two or three sequential applications. In 2019, topramezone with or without paclobutrazol, Fe chelate or turfgrass pigment injured creeping bentgrass < 15% in the first and second sequential applications. Results from these trials indicate that treatments included paclobutrazol and Fe chelate application programs were the most effective because they increased turfgrass quality and reduced bleaching injury caused by topramezone. We conclude that topramezone applications with combinations of paclobutrazol, Fe chelate, or turfgrass pigment should reduce potential for creeping bentgrass injury.

NativeKlean™ Herbicide (Aminopyralid + 2,4-D): A New Herbicide for Native Grass Roughs on Golf Courses. David E. Hillger*[1], Amy L. Agi[2], Paul Marquardt[3]; [1]Corteva Agriscience, Thorntown, IN, [2]Corteva Agriscience, Brooks, GA, [3]Corteva Agriscience, Des Moines, IA (508)

Naturalized areas are an increasingly common trend on golf courses. These areas of tall grass and native vegetation not only reduce inputs, but they enhance wildlife habitat; however, these areas still require maintenance. To simplify native and naturalized area management, NativeKlean™ herbicide, the premix of aminopyralid and 2,4-D amine, was specifically designed to be a low-maintenance solution. With application flexibility and long residual control, NativeKlean enables efficient use of limited resources while controlling high-anxiety herbaceous weeds, including

Canada thistle (*Cirsium arvense*), cocklebur (*Xanthium strumarium*), horsenettle (*Solanum carolinense*), pigweed (*Amaranthus spp.*), plantain (*Plantago spp.*) and ragweed (*Ambrosia spp.*).

Winter Slicing and Herbicides Affect Bermudagrass (*Cynodon dactylon*) Control in Creeping Bentgrass. Shawn Askew*, Jordan M. Craft, John Brewer; Virginia Tech, Blacksburg, VA (509)

Bermudagrass (*Cynodon* dactylon L.) is a persistent and troublesome weed in creeping bentgrass (*Agrostis stolonifera* L.) fairways throughout the transition zone. The persistence of bermudagrass in bentgrass fairways reduces turf quality due to differences in growth habit, leaf texture, and color. Selectively controlling bermudagrass in bentgrass is challenging because most herbicides that control bermudagrass are often injurious as well. Previous research suggest proper timing can maximize bermudagrass control in the fall when creeping bentgrass is actively growing and bermudagrass is going into dormancy. However, no research has examined a combination of mechanical and chemical programs for bermudagrass control in the fall. Therefore, the objective of this research was to evaluate herbicide and mechanical slicing programs for bermudagrass control in bentgrass fairways. Three field trials were initiated in the fall of 2017 and 2018 to evaluate herbicide and slicing programs for bentgrass tolerance and bermudagrass control. Six 8 treatment trials were initiated in September with four being at the Glade Road Research Facility in Blacksburg, VA and two at the Ballyhack Golf Course in Roanoke, VA. In Blacksburg, VA, one trial was established on a pure stand of 'L93' creeping bentgrass to evaluate tolerance with the other trial being established on a pure stand of 'Patriot' bermudagrass to evaluate bermudagrass control. The trial at Ballyhack Golf Course in Roanoke, VA was established on a creeping bentgrass fairway that was infested (40 to 50%) with bermudagrass to evaluate both bentgrass tolerance and bermudagrass control. Treatments were arranged as a RCBD factorial design with four replicates. All treatments consisted of three applications at two week-intervals accompanied by slicing. Three additional slicing events occurred 2, 4, and 8 weeks after the last herbicide treatment. Treatments programs included all combinations of four levels of herbicide: non-treated, topramezone at 6.4 g ai ha^{-1} + triclopyr at 26 g ai ha^{-1}, ethofumesate at 841 g ai ha^{-1}, topramezone at 6.4 g ai ha^{-1} + triclopyr at 26 g ai ha^{-1} + ethofumesate at 841 g ai ha^{-1}, and two levels of slicing, which are slicing and no slicing. All topramezone-containing treatments included a methylated seed oil adjuvant at 0.5% v v^{-1}. When assessed early summer in the year following treatment, slicing treatments combined with topramezone + triclopyr and the same with ethofumesate added to the mixture controlled bermudagrass 40 to 90% across 4 site years and better than ethofumesate alone. Slicing improved bermudagrass control in the fall during or soon after treatments were applied, but bermudagrass control was equivalent or only slightly improved by slicing in the following year. Slicing slightly increased creeping bentgrass injury. Topramezone + triclopyr with slicing injured creeping bentgrass no more than 39% and less than when ethofumesate was added to the mixture.

Control of Bermudagrass (*Cynodon dactylon*) with Dazomet, Glyphosate, and Glyphosate Alternatives. Fred Yelverton*[1], Patrick E. McCullough[2], Travis Gannon[1]; [1]North Carolina State University, Raleigh, NC, [2]University of Georgia, Griffin, GA (510)

Control of Bermudagrass (*Cynodon dactylon*) with Dazomet, Glyphosate, and Glyphosate Alternatives. Field experiments were conducted at the Turfgrass Field laboratories at North

Carolina State University in Raleigh, NC and Griffin, GA to identify methods to control bermudagrass without methyl bromide. Experiments were conducted in a randomized complete block design (RCB) with four replications on common or hybrid bermudagrass grown as turfgrasses. Plot size varied from 3m x 3m to 1.5m x 1.5m. Spray treatments were applied at a carrier volume of 300 L ha^{-1} to 375 L ha^{-1} with a CO_2 backpack sprayer at a pressures of 230 kPa to 275 kPa. Flat fan nozzles were used in all trials. Data were analyzed as an RCB design by ANOVA and means were separated according to Fishers protected LSD P=0.05. Sprayable herbicides tested were 3.3 kg ha^{-1} glyphosate, 0.42 kg ai ha^{-1} fluazifop, 0.36 kg ai ha^{-1} sethoxydim, 0.09 kg ha^{-1} quizalofop, 1.1 kg ai ha^{-1} clethodim or 1.7 kg ai ha^{-1}glufosinate. Dazomet 99G was applied via a drop spreader at 290 kg ai ha^{-1}, 467 kg ai ha^{-1}, or 582 kg ai ha^{-1}. At the Raleigh location, dazomet was applied on 1 June alone or glyphosate + fluazifop was used as a 7 day pretreatment to dazomet. Dazomet was either tilled or watered in and tarp vs no tarp. Bermudagrass cover was evaluated 8, 15, and 46 weeks after treatment (WAT). Repeat applications of glyphosate + fluazifop provided excellent control of bermudagrass. At 46 WAT, 2 applications of glyphosate + fluazifop (applied 28 days apart) resulted in on 5% recovery. Three applications at 28 day intervals resulted in only 1% recovery at 46 WAT. One application of glyphosate + fluazifop resulted in 30% bermudagrass recovery 46 weeks. Tilling plots following a single glyphosate + fluazifop application resulted in 55% of bermudagrass recovery at 46 weeks. The best control of bermudagrass (1% recovery) in the shortest amount of time was glyphosate + fluazifop treatment applied 7 days prior to 582 kg ai ha-1 dazomet and watered in. This treatment completed the application regime in 7 days compared to 56 days for 3 applications of glyphosate + fluzaifop. Furthermore, no tarping was necessary for dazomet when pretreated with glyphosate + fluazifop. At both GA and NC sites, similar trials have been initiated to evaluate herbicide programs to remove bermudagrass that do not include glyphosate. Evaluations have proceeded to 18 WAT at the NC site and 6 (WAT) at the GA site. The final evaluations will occur in the summer of 2020. To date, clethodim + fluazifop or glufosinate + fluazifop applied prior to dazomet are providing good control at 18 WAT. At the GA site, only fluazifop or fluazifop + glufosinate are providing control similar to glyphosate treatments at 6 WAT. Final evaluations will be made in the summer of 2020.

Consistent Efficacy and Defining the Use of ALS-Inhibiting Herbicides for Purple Nutsedge (*Cyperus rotundus*) Control in Turf. Kai Umeda*; University of Arizona, Phoenix, AZ (511)

The acetolactate synthase (ALS) -inhibiting herbicides, imazaquin and halosulfuron were found to be highly effective against purple nutsedge in bermudagrass turf in the mid-1980's. Generally, multiple applications alone or in combination with MSMA resulted in very good control at the end of the summer growing season. MSMA was regulated to very limited use and more recently, sulfentrazone exhibited comparable burndown efficacy. ALS-inhibiting herbicides following sulfentrazone applications gave good control of nutsedge. Sequential applications of ALS-inhibiting herbicides in July followed by another in August were consistently effective with trifloxysulfuron and sulfosulfuron providing 80-90% control at the end of summer. Imazaquin and halosulfuron still consistently demonstrate early efficacy comparable to trifloxysulfuron and sulfosulfuron but the end of summer control was only 50-70%. More recently, flazasulfuron, imazosulfuron, and pyrimisulfan have followed with the same use pattern and demonstrated effective nutsedge control for 2-6 weeks after the first application and extended control after the second application. Halosulfuron combined with foramsulfuron plus thiencarbazone offered improved control over halosulfuron alone. Sulfentrazone combined with imazethapyr provided extended length of control compared to sulfentrazone alone. Two July followed by August applications of ALS-inhibiting herbicides have been consistently effective for reducing purple nutsedge populations in bermudagrass turf.

Weed Management in Carbon Seeded Kentucky Bluegrass and Perennial Ryegrass. Raul Arroyo Rosas[1], Tara L. Burke*[2], Rachel J. Zuger[1], Ian Burke[1]; [1]Washington State University, Pullman, WA, [2]Washington State University, Albion, WA (512)

Rattail fescue (Vulpia myuros) is a problematic weed for grass seed growers in the Pacific Northwest due to the lack of effective herbicide treatments during establishment of Kentucky bluegrass (Poa pratensis) and perennial ryegrass (Lolium perenne). Previous research identified indaziflam and pyroxasulfone combined with a 2.5 cm wide band of activated carbon over the top of the seeded row as an effective option for control of rattail fescue. Indaziflam and pyroaxasulfone were evaluated for the management of Vulpia myuros in carbon-seeded P. pratensis and L. perenne grown for seed at the USDA Central Ferry Farm and at the Cook Agronomy Farm near Pullman, WA. Vulpia myuros stand density was different among sites. At Central Ferry, indaziflam applied PRE at 7.3, 14.6 g ai ha-1 or pyroxasulfone applied PRE at 89 or 179 g ai ha-1 completely controlled V. myuros PRE (0 plants m^{-1}). When indaziflam was applied POST, V. myuros density was 29 to 49 plants m^{-1} and was similar to pyroxasulfone applied POST (25-44 plants m^{-1}) and the nontreated control (21-32 plants m^{-1}). At Pullman WA[IB1] , indaziflam applied PRE resulted in densities of V. myuros that ranged from 56-77 plants m^{-1}. POST applications of pyroxasulfone resulted in densities of V. myuros that ranged from 46-60 plants m^{-1}. POST applications of indaziflam (28-45 plants m^{-1}) were similar to the PRE application of pyroxasulfone (15-26 plants m^{-1}) compared to the nontreated control (74-75 plants m^{-1}).

Improving Tolerance of Pollinator-Serving Plants to Herbicides Using Band-Applied Charcoal. Shawn Askew*, Jordan M. Craft, Morgan Shock; Virginia Tech, Blacksburg, VA (513)

Pollinator-serving plants have become a popular landscape addition in recent years. Most plants used for this purpose are slow-establishing perennials. Successful pollinator gardens often require intensive hand removal of weeds during establishment or several years of successional displacement of unwanted weeds. Traditionally, leaders in the pollinator plant industry discourage the use of synthetic herbicides. Thus, limited research has evaluated herbicides as a tool to aid establishment of pollinator-serving plants. As desire for pollinator services moves more mainstream, professionals in the landscape industry need methods for rapid plant establishment and pest control. Preemergence herbicides would be ideal for reducing weed pressure during establishment of slow-growing, perennial plants. Species diversity and variable seedling vigor of pollinator plants, however, reduces application of preemergence herbicides to aid plant establishment. Activated charcoal applied in narrow bands over planted rows can impart safety to desired plants and allow preemergence control of weeds in row middles. To test this technique for a variety of pollinator-serving plants, greenhouse and field studies were conducted in Blacksburg, VA. Our objective was to determine the influence of four activated-charcoal treatments on four pollinator-serving plant's response to diuron, indaziflam, oxadiazon, isoxaben, dimethenamid, flumioxazin, imazapic, and pendimethalin. Activated charcoal powder was mixed with 0.1% w/w xanthan gum and suspended in water at 13.9 kl solution per kg charcoal powder. The charcoal solution was applied to native silt-loam soil mixed 2:1 with Profile Greens-grade ceramic in 1 dm^2 pots. Charcoal treatments included: none, 336 kg/ha over the soil surface (OT), 672 kg/ha OT, and 672 kg/ha half OT and half in furrow. After applying charcoal, the following herbicides treatments were applied: At 3 weeks after seeding (WAS) when herbicide was not applied, *Coreopsis lanceolata* had 12 plants dm^{-2} which was over twice as many emerged plants as *Rudbeckia fulgida* and *Chamaecrista fasciculata* and four times as many emerged plants as *Monarda fistulosa*. Pendimethalin did not reduce plant emergence of any of these species, indaziflam did not reduce emergence of *R. fulgida* or *C. fasciculata*. Diuron reduced emergence of all species. At 10 WAS, pendimethalin reduced height of *C. fasciculata* from 15 to 8 cm but did not affect height of other species. Indaziflam reduced height of *C. fasciculata* and *M. fistulosa*. Diuron reduced height of all species. When no charcoal was used, plant emergence 3 WAS was generally reduced compared to charcoal-treated pots. When 672 kg/ha charcoal was applied half OT and half in furrow, plant emergence was numerically highest and statistically equivalent to nontreated pots in all cases. Field results were more dependent on species and charcoal application method than on herbicide. Splitting charcoal applications half in furrow and half over the top generally improved shoot density 1 year after treatment.

Evaluating Preemergent Herbicides for Use in Tropical Plants. Nathan Boyd[1], Shawn T. Steed*[2]; [1]University of Florida, Balm, FL, [2]University of Florida, Seffner, FL (514)

Florida produces large quantities of container grown tropical woody and foliage plants for use within the state and export. Labor to control weeds in containers is a major cost to nursery growers. To reduce these costs preemergence herbicides are typically used. However, there is little information on plant safety for growers using preemergence herbicides for tropical plant production. Experiments were conducted at the Gulf Coast Research and Education Center, Balm, FL to evaluate Spect(i)cle™ G, Broadstar™, Tower®, OH2®, Freehand® 1.75G, Showcase™, Snapshot® 2.5 TG, and Gemini®3.7 SC for use on *Stromanthe sanguinea* 'Triostar' (stromanthe), *Codiaeum variegatum* 'Mammy' (croton), and *Philodendron selloum* (philodendron), *Schefflera arboricola* 'Trinette' (arbicola), *Cordyline fruticose* 'Red Sister' (coryline), *Ixora coccinea* 'Maui Red' (ixora), and *Plumbago auriculata* 'Dark Blue' (plumbago), *Allamanda schottii* (allamanda), *Strelitzia reginae* (orange bird of paradise), *Hamelia patens* (firebush) and *Hibiscus rosa-sinensis* 'Painted Lady' (hibiscus). Broadstar™ caused low-level damage in philodendron. Spect(i)cle™ G, OH2®, and Showcase™ caused low level damage in stromanthe. None of the herbicides evaluated damaged crotons, arbicola, cordyline, ixora, or plumbago with the exception of Broadstar™ which caused low-level damage in cordyline. Spect(i)cle™ G, Broadstar™, Showcase™, and Snapshot® were safe for use on Allamanda. Spect(i)cle™ G, Tower®, OH2®, Showcase™, Snapshot® and Gemini® were safe for use on bird of paradise. Spect(i)le™ G, OH2®, Showcase™, and Snapshot® were safe for use on firebush. All herbicides evaluated were safe for use on hibiscus.

WSSA SECTION 8: FORMULATION, ADJUVANT, AND APPLICATION TECHNOLOGY

Assessment of Commercial Scale Dicamba and 2,4-D Drift Using Drift Reducing Adjuvants. Ryan J. Edwards*[1], Lillian C. Magidow[1], Steven A. Fredricks[1], Gregory K. Dahl[2]; [1]WinField United, River Falls, WI, [2]WinField United, Eagan, MN (583)

Off target movement of dicamba and 2,4-D herbicides must be minimized by pesticide applicators using technologies effective in reducing the off target movement. Off target dicamba movement has been shown to be reduced when drift reducing adjuvants are added to spray mixtures. With the commercialization of the new 2,4-D technologies, drift reduction when combined with tank-mixtures and adjuvants required investigation. A commercial scale sprayer was used to assess the effects of different drift reducing materials when applied in windy field conditions. Data were collected downwind using repeated horizontal transects, air samplers and NDVI images from a fixed wing drone. Results showed drift reductions when paired with adjuvants were specific to the two chemistries tested. With dicamba, off target drift was greater than with 2,4-D regardless of adjuvant addition. When adjuvants were added to tank mixtures, visible reductions in off target movement were achieved.

Survey of Commercial Sprayers in Alabama for Dicamba Residue Retention Following Triple Rinse with Water. Frances B. Browne*, Steve Li, Katilyn J. Price; Auburn University, Auburn, AL (584)

Field and laboratory experiments were conducted in 2017 and 2019 to investigate the risk for sprayer contamination following dicamba applications. Three commercial sprayers were evaluated in 2017 for dicamba residue retention following four cleanout protocols. Hagie Upfront STS 10, John Deere 6700, and SprayCoupe 4660 sprayers with tank capacities of 3570 L, 1590 L, and 1580 L, respectively, were used to apply dicamba (Clarity) at 1.12 kg ae ha^{-1} with a carrier volume of 93.5 L ha^{-1}. One cleaning method was triple rinse with water and the remaining three included a first rinse of 3% v/v ammonium, third rinse of water and the second rinses were either glyphosate, Fimco, or Protank detergent at 5.11 kg ai, 0.90 kg, and 0.95 L per 378.5 L water, respectively. For each rinse, 378.5 L of water and assigned cleaning agent were added. Half of the cleaning solution was sprayed out before rinsate samples were collected from the left, middle, and right sections of the boom simultaneously for each rinse. A fourth rinse using only water was included to demonstrate the cleaning efficacy of each triple-rinse protocol. All cleaning protocols were repeated three times in the field. Higher dicamba concentrations were detected in the Haige Upfront STS 10, suggesting sprayers with larger tank capacities may be more difficult to clean. However, concentrations of final rinsates did not exceed 1.25 ppm (equivalent to 0.12 g ae ha^{-1} at 93.5 L ha-1 output) regardless of cleanout method or sprayer and at least 99% of initial dicamba contaminant was removed by the third rinse. Furthermore, fourth rinsates were applied to sensitive soybean and no yield response was observed. These data suggest triple rinse with water is sufficient for dicamba removal from sprayer equipment. To further test efficacy of this protocol, a survey of 25 commercial agriculture sprayers was conducted in 2019. Sprayers were mixed for 15% tank capacity with dicamba (Xtendimax) at 560 g ae ha^{-1} + a drift reduction agent (Intact) at 0.5% v/v and calibrated for a carrier volume of 140 L ha^{-1}. Following applications, four rinses of water were conducted at 15% tank capacity and rinsates were collected from the left, middle, and right sections of the boom at each of the four rinses. Similar to the replicated study, majority of sprayers retained less than 1% of initial dicamba contaminant by the third rinse. Rinsates collected at the fourth rinse did not exceed 0.2 ppm for 88% of the sprayers tested (22 sprayers). The remaining 3 sprayers had concentrations of 0.47 to 1 ppm. However, these concentrations are not likely to result in soybean yield loss. Dicamba clean out efficacy was not affected by tank size and boom length in this survey. Concentrations detected in left, middle, and right sections of the boom did not differ for individual rinses. New dicamba formulation labels require a triple rinse cleanout procedure following applications. These data suggest triple rinse with water is sufficient for dicamba removal regardless of formulation used.

Fatty Acid Methyl Ester Ethoxylates: A New Surfactant and Adjuvant for Crop Protection. Dean Oester*[1], Timothy H. Anderson[2]; [1]BASF, Cincinnati, OH, [2]BASF Corporation, Cincinnati, OH (585)

Fatty acid methyl ester ethoxylates represent a new type of nonionic surfactant and adjuvant for the crop protection market. Agnique® ME 818-5 is a mixture of methyl ester ethoxylates comprised of C8 to C18 fatty alkyl chains. This product has a low melting point (-2 - 10°C) and high flash point (119°C) making it both easy and safe to handle and transport. It exhibits a low equilibrium surface tension (31 mN/m) and CMC (38 ppm at 23°C) making it an excellent surfactant or co-surfactant. And the unique structure of ME 818-5 affords it high solubility in both aqueous and organic solvent systems. Five field trials have been conducted with ME 818-5 alone or with blends containing ME 818-5 as tank mix adjuvants in combination with commercially available concentrates of potassium glyphosate plus the sodium salt of fomesafen, ammonium glufosinate plus clethodim, mesotrione, 2,4 D choline salt and the diglycolamine (DGA) salt of dicamba. The results of these five field trials will be summarized and will show that ME 818-5 is an effective adjuvant alone or in combination with other nonionic surfactants across this range of herbicides. ME 818-5 alone (0.5% v/v) with potassium glyphosate plus sodium fomesafen gave enhanced control ($p = 0.05$) of Palmer amaranth, common lambsquarters and large crabgrass over the potassium glyphosate plus sodium fomesafen herbicide alone treatment 7 and 14 DAT. ME 818-5 alone (0.5% v/v) and as a component in adjuvant blends (0.5% v/v total) with the DGA salt of dicamba gave improved control of giant ragweed and common lambsquarters ($p = 0.05$) over the DGA salt of dicamba alone treatment 14 and 21 DAT. Fatty acid methyl ester ethoxylates (Agnique® ME 818-5) represent a new tool for growers to consider in their weed control management programs to improve the efficacy of commercially available herbicides.

Evaluating Weed Control Efficacy of Dicamba and Dicamba/tembotrione with and without Ammonium Sulfate in Corn in the Midwest. Ethann R. Barnes[1], Brian Dintelmann[2], Kevin W. Bradley[2], Aaron Hager[3], Amit J. Jhala*[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Missouri, Columbia, MO, [3]University of Illinois, Urbana, IL (586)

Ammonium sulfate (AMS) is known to increase volatility of dicamba and is prohibited to mix with new dicamba products labeled in dicamba-resistant soybean. While AMS is labeled and applied with dicamba based herbicides in corn/sorghum, to reduce chances of dicamba volatility, it should not be used. Applying dicamba without AMS may result in reduced weed control. Therefore, field experiments were conducted in Illinois, Missouri, and Nebraska during the 2018 and 2019 growing seasons to: 1) evaluate efficacy of dicamba (DiFlexx) or dicamba/tembotrione (DiFlexx DUO) applied with and without AMS or with AMS replacement and 2) evaluate if higher labeled rate of dicamba or dicamba/tembotrione may provide better weed control. In Nebraska and Illinois, control of Amaranthus species was reduced with dicamba (840 g ai/ha) when AMS replacement was used (77%) compared to when AMS + COC (crop oil concentrate) was mixed (93%) at 14 DAT; however, no difference was observed in Missouri. In Nebraska and Illinois, velvetleaf control with dicamba at higher rate (1,120 g ai/ha) applied alone (73%) was improved with the addition of AMS + COC (96%) and AMS replacement (94%) 14 DAT. When higher rate of dicamba (1,120 g ai/ha) was used there was no difference in weed control between AMS + COC and AMS replacement at 14 and 56 DAT in Nebraska, Illinois, and Missouri. The higher labeled rates of dicamba or dicamba/tembotrione with AMS replacement often improved weed control compared to the lower rates of dicamba with AMS replacement in Illinois but not in Nebraska or Missouri. Amaranthus species density was reduced to 26 plants/m^2 when AMS + COC was added to dicamba (1,120 g ai/ha) compared to dicamba alone (64 plants/m^2) in Nebraska 14 DAT; however, no difference was observed for any state at 56 DAT. Broadleaf weed biomass and corn yield was not affected between dicamba products and rates in presence or absence of AMS or AMS replacements. It is concluded that dicamba or dicamba/tembotrione can be applied with AMS or AMS replacement when using the higher labeled rates in corn without compromising weed control or corn yield.

Efficacy of Three New Adjuvant Formulations on Herbicide Performance Across the Mid-Western United States. Jim T. Daniel*[1], Tom Hoverstad[2], Paul O. Johnson[3], Scott Parrish[4], Bruce Potter[5], Prashant Jha[6], Philip Westra[7]; [1]Daniel Ag Consulting, Keenesburg, CO, [2]University of Minnesota Southern Research and Outreach Center, Waseca, MN, [3]South Dakota State University, Brookings, SD, [4]AGRASYST, Spokane, WA, [5]University of Minnesota Southwest Research and Outreach Center, Lamberton, MN, [6]Iowa State University, Ames, IA, [7]Colorado State University, Fort Collins, CO (587)

The effects of three new adjuvants from AgraSyst Inc. were evaluated in both greenhouse and field trials. AGRASYST 90 ™ is a blended nonionic surfactant composed of low and high HLB numbers, humectants, and a cat ionic component, tallow amine. Two greenhouse trials showed that glyphosate performance increased with the addition of each component. Field trials were conducted by researchers from Iowa State University, South Dakota State University, University of Minnesota, and Colorado State University with glyphosate and paraquat showed excellent performance. LOW DRIFT 90 is basically AGRASYST 90 with the addition of a drift reduction agent. LOW DRIFT 90 had similar efficacy effects as AGRASYST 90. Droplet Scan evaluation from an aerial application showed DV10 a little above 300 microns and increased percent coverage over standard nonionic surfactants. MAXSO ™ is a high surfactant load (including tallow amine) MSO. MAXSO was evaluated by the same researchers above with tembotrione in corn. In all trials, performance and yield was equal to the MSO standards.

Plant Macro- and Micronutrients Formulated as Effective Environmentally Benign Postemergence Herbicides. David A. Cobb*; Belvedere Foliar LLC, Belvedere, CA (588)

A new herbicide type is described consisting of active and adjuvant ingredients that are considered non-toxic, environmentally benign, and safe to transport, mix, and apply. The formulations are applied as aqueous solutions for postemergence, non-selective weed control. All active ingredients are based on a plant macro- or micronutrient. Herbicidal action follows an accumulation of nutrient on plant surfaces and/or internal tissue at levels high enough to kill the plant by a process described as "nutrient disruption". Whether death is by burndown or from systemic action depends on the formula and application rate. Highly effective herbicidal activity was observed for the Belvedere Foliar potassium-based formula BF1002 applied topically in greenhouse and field trials, with 90 to 100% observed control at 21 days after treatment for many common North American weeds, including but not limited to Palmer amaranth (*Amaranthus palmeri*), redroot pigweed (*Amaranthus retroflexus*), velvetleaf (*Albutilon theophrasti*), hemp sesbania (*Sesbania herbacea*), kochia (*Kochia scoparia*), and German foxtail (*Panicum italicum*). The benign chemical nature of the formulas is especially appropriate for municipal, landscape, turf, and home & garden markets. It is anticipated that many Belvedere Foliar formulas can achieve OMRI certification or be registered as "biochemicals" that will expedite USEPA registration. The Belvedere Foliar fundamental concept of "nutrient disruptive herbicidal action" has been awarded a US patent; additional US and international patents are pending.

Quizalofop-P-Ethyl: Adjuvants, Nitrogen Fertilizer, and Tank-mixtures - the Rest of the Story. Richard K. Zollinger*[1], Peter J. Porpiglia[2], Mark L. Bernards[3], Jerry M. Green[4], Kirk A. Howatt[5], Prashant Jha[6], Greg R. Kruger[7], Christy Sprague[8], Mark VanGessel[9], Bryan G. Young[10]; [1]Amvac Chemical Company, Spokane, WA, [2]Amvac Chemical Company, Newport Beach, CA, [3]Western Illinois University, Macomb, IL, [4]Green Ways Consulting LLC, Landenberg, PA, [5]North Dakota State University, Fargo, ND, [6]Iowa State University, Ames, IA, [7]University of Nebraska-Lincoln, North Platte, NE, [8]Michigan State University, East Lansing, MI, [9]University of Delaware, Georgetown, DE, [10]Purdue University, Brookston, IN (589)

Field research was conducted in 2019 in Nebraska, North Dakota, Missouri, and Michigan to evaluate weed efficacy from quizalofop-P ethyl ester (quizalopfop) applied with nonionic surfactant (NIS), petroleum oil concentrate (POC) and methylated seed oil (MSO) concentrate adjuvants, and ammonium sulfate (AMS). Quizalopfop was applied at 31.5 g ae/ha with adjuvants on assay species of corn, wheat, barley, and tame millet that were planted in strips perpendicular to each plot. NIS was applied at 0.25% v/v, POC and MSO concentrate adjuvants were applied at 1% v/v, high surfactant methylated oil (HSMOC) adjuvants were applied at 0.5% v/v, and AMS was applied at 3.43 kg/ha. Quizalofop efficacy increased with adjuvants in the following order: POC>MSO=HSMOC>NIS. AMS was neutral or negative in affecting quizalofop activity. Field research was conducted in 2019 in Nebraska, North Dakota, Minnesota, and Michigan to evaluate weed efficacy from quizalofop-P ethyl applied alone and with mesotrione (107 g ae/ha), topramezone (19 g ae/ha) , glufosinate (460 g ae/ha), 2,4-D-dimethyl amine salt (814 g ae/ha), and dicamba (571 g ae/ha) with MSO (1% v/v) and AMS (3.43 kg/ha). Quizalopfop was applied at 47 g ae/ha with mesotrione, topramezone, glufosinate, 2,4-D, and dicamba with adjuvants on assay species of corn, wheat, barley, and tame millet that were planted in strips perpendicular to each plot. Mesotrione and topramezone herbicides had a neutral affect on quizalofop activity. Glufosinate increased grass control when applied with quizalofop. 2,4-D amine and dicamba growth regulator herbicides antagonized grass control from quizalofop. Field research was conducted in 2019 in Nebraska, Iowa, Mississippi, and Delaware to evaluate weed efficacy from quizalofop applied alone or with 2,4-D-choline salt (814 and 1086 g ae/ha) with POC (1% v/v) and AMS (3.43 kg/ha). Quizalopfop was applied at 63 and 94 g ae/ha with 2,4-D or 7 days following application of 2,4-D with adjuvants on assay species of corn, wheat, barley, and tame millet that were planted in strips perpendicular to each plot. 2,4-D-choline salt antagonized grass control from quizalopfop when applied in tankmix. Increasing quizalofop rate from 63 to 94 g ae/ha overcame 2,4-D herbicide antagonism. 2,4-D-choline salt did not antagonize grass from quizalofop when applied 7 days before quizalofop. AMS did not increase grass control or overcome 2,4-D-choline antagonism of quizalofop. An endemic population of barnyardgrass that was treated with quizalofop was not controlled by any treatment. Barnyardgrass control declined at each successive evaluation timing. It is theorized that the ethyl ester formulation of quizalofop-P, low pKa of quizalofop-P, and differential absorption rates between quizalofop-P and tankmix herbicides are relevant physical property that voids enhancing quizalofop-P activity from MSO based adjuvants and from AMS. These properties may also impart in a neutral response when quizalofop-P is applied with some herbicides that effect photosynthesis.

Shear Stabilization of High Molecular Weight Drift Control Polymers. Timothy H. Anderson*[1], Dean Oester[2], Melvin Long[1]; [1]BASF Corporation, Cincinnati, OH, [2]BASF, Cincinnati, OH (590)

High molecular weight polymers are the additives of choice when the need arises to modify droplet patterns to mitigate spray drift. It has long been known that under adverse shear conditions, these polymers do not contribute to lower V% of driftable fines. Most recently, the effect of pump shear on drift control polymers has been presented to the industry. This paper is intended to offer technical solutions to maintain low drift spray patterns. Data will be presented to show the relative merits of polymer modification, and/or addition of stabilizing additives to prevent increased fine droplets due to pump shear. Shear stabilization will be shown for applications using air-induction and traditional flat fan nozzles with a variety of pesticide spray solutions.

Mirror, Mirror on the Wall: What's the Best Adjuvant of Them All. Joe V. Gednalske[1], Gary Halvorson*[2]; [1]Council of Producers & Distributors of Agrotechnology, Washington, DC, [2]Council of Producers and Distributors of Agrotechnology, Washington, DC (591)

Most postemergence herbicides often require the use of a tank-mix adjuvant to maximize weed control. The complexity of choosing the correct adjuvants has increased due large number of adjuvants available and the increase in tank mixes of 3 or more herbicides in a typical application. A review of weed control data shows huge variation in weed control efficacy depending on the adjuvant used. Options are presented to reduce the complexity. A solicitation is presented to the Weed Science Society of America members to assist with more adjuvant research!

The Influence of Adjuvants and Tank-Mix Products on the Performance of New Dicamba and 2,4-D Herbicides. Gregory K. Dahl*[1], Ryan J. Edwards[2], Lillian C. Magidow[2], Annie Makepeace[2], Joshua J. Skelton[3], Steven A. Fredericks[2], Andrea C, Clark[2]; [1]WinField United, Eagan, MN, [2]WinField United, River Falls, WI, [3]WinField United, Saint Paul, MN (592)

Studies were conducted with the new dicamba and 2,4-D herbicides in and prior to 2019. The studies consisted of field efficacy and drift studies, wind tunnel spray analysis studies and chemical compatibility studies. Products tested with the 2,4-D and dicamba herbicides included other herbicides, insecticides, fungicides, adjuvants, fertilizers and other products. The performance of dicamba tank-mixtures for controlling weeds was increased when dicamba was used with non-AMS water conditioning adjuvants. The performance of 2,4-D tank-mixtures for controlling weeds was increased when used with AMS containing adjuvants or with non-AMS water conditioning adjuvants. Oil adjuvants and surfactant adjuvants were able to improve weed control with tank mixtures containing the 2,4-D or dicamba herbicides. Drift reducing adjuvants were able to decrease the amount of spray that consisted of driftable fine droplets with either new 2,4-D or dicamba herbicides. Many products were able to be tank-mixed with the new 2,4-D or dicamba herbicides alone or with drift reducing adjuvants without adversely affecting spray drift quality. Many products were compatible with at least one of the 2,4-D or dicamba technologies. Some products were compatible with all of the new technologies. There were many products that were not compatible with at least one of the new technologies.

Optimizing the Oxford P15 for Droplet Spectrum Measurement and Spray Analysis in the Field and Laboratory. J Connor Ferguson*[1], Justin S. Calhoun[2], Kayla L. Broster[1], Zachary R. Treadway[1], Zaim Ugljic[1]; [1]Mississippi State University, Mississippi State, MS, [2]Mississippi State University, Starkville, MS (593)

The Oxford P15 utilizes a high-speed camera plus LED strobe to capture sprays – up to 15,000 particles per second. Its software measures difference between particles frame by frame which can capture velocity. It can not only provide data but can also provide images of the sprays. Unlike laser diffraction, imaging systems use direct measurement of particle size. The Oxford P15 captures the image of the spray and utilizing designed software, calculates the size of the particle in the image. It can be used stationary or could be designed for use in the field. This instrument won't replace laser diffraction or other measurement systems. The Oxford P15 allows for a greater flexibility with which to gather data for spray analysis. Taking a proven method like laser diffraction and designing Oxford measurement methods that are appropriate for data collection will be key moving forward. The Oxford P15 is a sound instrument for spray analysis and can be utilized in new ways to address considerations for applications. With the ability to measure sprays in the field and capture images, answering greater questions about performance of nozzles and adjuvants can be done.

The Effect of pH Modifying Adjuvants on Efficacy of Glyphosate + Dicamba Tank-Mixes. Joseph T. Ikley*[1], Mike Ostlie[2], Nathan H. Haugrud[1], Nicholas R. Steppig[3], Bryan G. Young[4]; [1]North Dakota State University, Fargo, ND, [2]North Dakota State University, Carrington, ND, [3]Purdue University, Lafayette, IN, [4]Purdue University, Brookston, IN (594)

Off-target movement of dicamba has become increasingly scrutinized since the introduction of dicamba-tolerant soybean in the United States in 2017. Volatility has been one of the most researched pathways of off-target movement of dicamba, and research has shown that low pH spray solutions increase volatility of dicamba. One common practice that lowers the spray solution pH is the addition of glyphosate, which is common for many dicamba applications in dicamba-tolerant soybean. Label changes for newly formulated dicamba products indicate that pH modifiers should be added to the spray tank if spray solution pH is lower than 5. Raising the pH of the spray solution above 5 should help reduce volatility, but there is little knowledge of the effect on herbicide efficacy when raising the pH of dicamba + glyphosate spray solutions. The objective of this research was to examine the effect on herbicide efficacy of glyphosate + dicamba tank-mixes by adding pH modifiers to the spray solution. Trials were established at the Davis Purdue Agricultural Center (DPAC) near Farmland Indiana, at the Carrington Research and Extension Center in Carrington North Dakota, and a site near Hillsboro North Dakota in 2019. Treatments consisted of adding one of three pH modifiers to spray solutions containing tank-mixes of the BAPMA salt of dicamba + a potassium salt of glyphosate (560 + 1260 g ha^{-1} and 280 + 630 g ha^{-1}). The pH modifiers were Ndemand 88 at 2.34 L ha^{-1}, Ndemand Entourage K at 2.34 L ha^{-1}, and Linkage at 1 % v/v. At each dicamba + glyphosate rate, there was a no-pH modifier control. The spray solution pH was measured prior to and after adding each pH modifier. Herbicide efficacy was rated 14 and 28 days after treatment (DAT) at each site. The addition of the pH modifiers increased the spray solution pH anywhere from 0.2 to 2.1 units depending on product and herbicide rate. The efficacy at 28 DAT indicate that the addition of pH modifiers have a variable effect on herbicide efficacy depending on product and weed species. The addition of a pH modifier did not affect efficacy on redroot pigweed (*Amaranthus retroflexus*) or common lambsquarters (*Chenopodium album*) at either dicamba + glyphosate rate. Waterhemp (*Amaranthus tuberculatus*) control was not affected by the addition of a pH modifier at the low rate of dicamba + glyphosate, however the addition of Ndemand Entourage K increased waterhemp control from 70% to 81% at the high rate of dicamba + glyphosate compared to no pH modifier. Conversely, the addition of any of the pH modifiers reduced green foxtail (*Setaria viridis*) control at the low rates of dicamba + glyphosate. Results indicate that pH modifiers do increase spray solution pH which will help reduce dicamba volatility, however the effect on dicamba + glyphosate efficacy may be difficult to predict depending on product choice and target weed species.

On-Farm Evaluations of Auxin Nozzles for Peanut Pest Management - Year 2. Eric P. Prostko*[1], Mark R. Abney[1], Robert C. Kemerait[1], Glen C. Rains[1], D. Scott Carlson[2], James L. Jacobs[3], D. Bryce Sutherland[2], William G. Tyson[4]; [1]University of Georgia, Tifton, GA, [2]University of Georgia Extension, Sylvester, GA, [3]University of Georgia Extension, Blackshear, GA, [4]University of Georgia Extension, Statesboro, GA (595)

In 2019, Georgia cotton growers planted auxin-tolerant varieties on 83% of the total acres [XtendFlex® (77%) and Enlist™ (6%)]. One of the requirements for the use of the auxin herbicides (dicamba or 2,4-D choline) on tolerant cotton varieties is that growers must use nozzle/pressure combinations that produce very-coarse to ultra-coarse droplets (VMD_{50} = 404 microns). Since most cotton growers are also peanut growers, there is much interest in using “auxin” nozzles for pest management in peanut. However, there is concern that these coarse droplet nozzles might not be adequate for the multitude of pesticides applied in peanut that have traditionally required maximum coverage. Therefore, large-plot (0.9 to 4.6 acres), replicated, on-farm peanut field trials were conducted in 2019 to compare the performance of flat fan nozzles to auxin nozzles using commercial application equipment. Trials were conducted in 3 counties including Bulloch, Pierce, and Worth. In Bulloch Co., a JD-4630 applicator (90' boom) calibrated to deliver 12 GPA (28 PSI, 12 MPH) was used to compare XRC-11004, TTI-11004, and TDXL-11004D nozzles. In Pierce Co., a JD-4730 applicator (100' boom) calibrated to deliver 15 GPA (18-20 PSI, 11.6 MPH) was used to compare XR-11006 and TTI-11006 nozzles. In Worth Co., a JD-4730 applicator (90' boom) calibrated to deliver 20 GPA (42-57 PSI, 12.5 MPH) was used to compare XRC-11006 and TTI-11006 nozzles. Droplet analyses of 21 kromekote spray cards (2” X 3”) using either DepositScan™ or DropletScan™ indicated that coverage (%) with the auxin nozzles was greater than with the flat fan nozzles in Bulloch and Pierce counties. VMD_{50} values for the auxin nozzles ranged between 411 to 481 microns while VMD_{50} values for the flat fan nozzles ranged between 182 to 384 microns. For the field studies, all agri-chemicals, including herbicides, fungicides, insecticides, and fertilizers routinely used by the grower, were applied with the different nozzle types (6 total applications/location, 4 replications/nozzle type/location). All data were subjected to ANOVA and means separated using Fisher's Protected LSD Test (P=0.10). In the field, no differences in weeds, insects, disease, and yield were observed at any location between nozzle types.

WSSA SECTION 10: BIOCONTROL OF WEEDS

Impacts of Weed Biocontrol in Hawaii. M Tracy Johnson*; USDA Forest Service, Volcano, HI (528)

Abstract not available

Mechanisms of Weed Seed Predation and its Potential Role in Weed Biocontrol. Khaldoun Ali*; University of Saskatchewan, Saskatoon, SK, Canada (529)

Paper withdrawn

Identification of a Potential Allelopathic Substance Involved in Allelopathic Activity of False Mangosteen (*Garcinia xanthochymus*). Md Mahfuzur Rob*[1], Keitaro Iwasaki[2], Arihiro Iwasaki[2], Kiyotake Suenaga[2], Hisashi Kato-Noguchi[1]; [1]Kagawa University, Miki, Japan, [2]Keio University, Yokohama, Japan (530)

Allelopathy is the effect of one plant on another plant mediated through the release of allelopathic substances referred to as allelochemicals. We investigated phytotoxic potential of *Garcinia xanthochymus* against five test plant species, cress, lettuce, rapeseed, Italian ryegrass, and timothy. The extracts of *G. xanthochymus* leaves caused remarkable inhibition on all the tested plants, and the inhibition was concentration- and species-dependent. Therefore, to discover specific compounds involved in the allelopathic activity of the *G. xanthochymus* extracts, bio-guided purification process through several column chromatographic steps including silica gel, sephadex LH-20, C18 cartridge, and reverse phase HPLC were carried out leading to isolation and identification of potent allelopathic substance and assigned as a novel compound, garcienone ((R, E)-5-hydroxy-5-((6S, 9S)-6-methyl-9-(prop-13-en-10-yl) tetrahydrofuran-6-yl) pent-3-en-2-one). Garcienone significantly inhibited the seedling growth of cress in a concentration dependent manner and required concentration for 50% growth inhibition (I_{50} values) for the root and shoot growth of cress were 120.5 and 156.3 µM, respectively. However, this report is the first to isolate and identify garcienone and to determine its phytotoxic potential. These observations suggest that garcienone might participate in the allelopathic activity of *G. xanthochymus* extract and can be utilized as a potential source of bioherbicide.

Inhibiting Herbicide Resistant Amaranthus by Suppressing Reproduction. Efrat Lidor Nili[1], Ido Shwartz[1], Herve Huet[1], Miriam Aminia[1], Micheal D. Owen[2], Jonathan Gressel[3], Orly Noivirt-Brik*[1]; [1]WeedOUT Ltd., Ness Ziona, Israel, [2]Iowa State University, Ames, IA, [3]Affiliation Not Specified, Rehovot, Israel (531)

Our new technology to control herbicide-resistant weeds is based on using irradiated weed pollen that outcompetes natural pollen, resulting in the formation of non-viable seeds. Weed pollen is harvested from weed plants and then irradiated with a carefully determined dose of X-ray - radiation that prevents cell divisions. The pollen is then applied in the field, leading to significant reduction in weed seedbank replenishment. Proof of concept of the technology was demonstrated using *Amaranthus palmeri* where newly formed seeds lost their ability to germinate. The effect of the irradiation treatment on pollen competitiveness was examined. Findings show that although there is a correlation between the irradiation dose and a reduction in pollen competitiveness, that did not prevent the irradiated pollen from being competitive in field conditions. The technology was tested in a 2018 field trial on *A. palmeri* in Israel resulting in a significant 60% reduction in the number of newly formed seeds. The treatment with irradiated pollen has a dual effect: besides resulting in aborted embryos, it also inhibits weed growth and new flower formation. The assumption is that the massive pollination (in contrast to gradual natural pollination) results in the shifting of resources in the female weed to (non-viable) seed production, leading to growth inhibition. This pollen-based strategy is meant to be supplementary to herbicides for controlling weed escapes as well as herbicide-resistant individuals after they have become a part of the population mid-season. Our pollen-based technology could be incorporated into integrated weed management programs that will significantly delay weed resistance spreading within the field and is expected to extend the lifetime of current herbicides. It should be possible to adapt this technology to other weed species.

Penology of *Dioscorea bulbifera* and its Co-evolved Natural-enemy *Lilioceris cheni*: Implication in Biological Control Efficacy in Florida. Min B. Rayamajhi*; USDA/ARS Invasive Plant Res Lab, Fort Lauderdale, FL (532)

Paper withdrawn

Developing a Microbial Herbicide to Control Amaranthus Weeds. Louis G. Boddy*, Tim Johnson; Marrone BIo Innovations, Davis, CA (533)

There are multiple examples of successful biofungicides, bioinsecticides and even bionematicides on the market, but no cases of widely adopted bioherbicides. Marrone Bio Innovations specializes in discovering, developing and marketing biopesticides from soil microbes, and has been developing MBI-014 as a microbial bioherbicide targeting broadleaf weeds, especially in the Amaranthus genus. MBI-014 is based on *Burkholderia rinojensis* strain A396, which produces an array of promising pesticidal natural products, including the secondary metabolites with molecular weights 540 and 519, that each function on novel herbicidal target sites and exhibit systemic activity. Optimization of the microbial production process has subsequently allowed for enhancement of herbicidal activity. Symptoms are visible at around three days after application (DAT), and full control of Palmer amaranth, waterhemp, redroot pigweed and species belonging to mustard, mallow and other broadleaf families is achieved by 6 DAT.

Progress on Classical Biological Control of Cogongrass (*Imperata cylindrica*) in the Southeastern United States. James P. Cuda*[1], Purnama Hidayat[2], Izza A. Putri[2]; [1]University of Florida, Gainesville, FL, [2]Bogor Agricultural University, Bogor, Indonesia (534)

Cogongrass is a federal listed noxious weed that is invasive in Florida and other southeastern states. This perennial rhizomatous grass was introduced into the Alabama initially as packing material from Japan, then from the Philippines into Mississippi as a forage crop in the early 1920s, and finally into Florida in the 1940s. Cogongrass is listed among the top ten worst weeds in the world because it crowds out native plants, provides poor forage to animals, and reduces pine forest productivity. Conventional control costs can exceed $400 per hectare because 60% of the biomass is underground. In 2009, the state of Alabama spent $6.3 million of federal stimulus funds exclusively for control with herbicides. Biological control using natural enemies of cogongrass has received little attention and no biocontrol agents have been introduced anywhere in the world. A potential biocontrol agent is an Indonesian gall midge *Orseolia javanica* Kieffer and van Leeuwen-Reijinvaan (Diptera: Cecidomyiidae). This insect impacts cogongrass by producing galls that serve as nutrient "sinks", which divert plant resources away from normal shoot production. In its native range, adults emerge early in the morning (4:30-6:00 am) and become active during early evening. Females deposit 400-500 eggs soon after mating. In the field, most eggs are deposited on the soil surface near the base of the plant and fertility is high (99%). Larvae hatch in ~ 5 days and bore into young, tender leaf sheaths near the apical meristem. Larval development and pupation induce the formation of pink and white linear galls. The life cycle (egg to adult) is completed in 33-57 days, depending on soil moisture. Gall length and adult emergence were significantly shorter in mowed versus unmowed cogongrass plots. Furthermore, gall density was positively correlated with rainfall.

WSSA SECTION 11: PHYSIOLOGY

Target Site-Based Resistance to ALS Inhibitors, Glyphosate, and PPO Inhibitors in a Palmer Amaranth Accession from Mississippi. Vijay Nandula*[1], Darci A. Giacomini[2], William T. Molin[1]; [1]USDA-ARS, Stoneville, MS, [2]University of Illinois, Urbana, IL (322)

Abstract not available

A Safener Does Influence Pacific Northwest Winter Wheat Varietal Response to Very-Long-Chain Fatty Acid-Inhibiting Herbicides. Damilola A. Raiyemo*[1], William J. Price[1], Traci Rauch[1], Joan M. Campbell[1], Fangming Xiao[1], Rong Ma[2], Timothy S. Prather[1]; [1]University of Idaho, Moscow, ID, [2]Bayer CropScience, Chesterfield, MO (323)

Annual grass weeds are consistent problems, reducing profitability to wheat farmers in the Pacific Northwest. Preemergence herbicide options for annual grass control in wheat are limited and their use may provide control. The herbicides *S*-metolachlor and dimethenamid-P control annual grasses but are not registered for use in wheat due to crop injury. The overall objective of this study was to evaluate safener protection of soft white winter wheat varieties from very-long-chain fatty acid-inhibiting herbicide injury. Previously, we reported response variation in 19 soft white winter wheat varieties to *S*-metolachlor and dimethenamid-P herbicides and varieties were placed in one of three categories with respect to safener response: 1) variety responded, 2) mixed response across two experimental runs or 3) no response. Six soft white winter varieties, 2 from each response category were selected: 1) UI Sparrow, LWW 15-72223, 2) Brundage 96, UI Magic CL+ 3), UI Palouse CL+, UI Castle CL+ and were evaluated for response to incremental doses of fluxofenim at 0.2, 0.4, 0.6, 0.8, 1.6 and 3.2 g ai kg^{-1} seed to identify any negative effects to the varieties. Additionally, a fluxofenim dose response experiment was conducted with UI Sparrow, Brundage 96 and UI Castle CL+ in the presence of *S*-metolachlor at 1010 g ai ha^{-1}, dimethenamid-P at 647 g ai ha^{-1} or pyroxasulfone at 246 g ai ha^{-1}. Finally, an experiment measuring glutathione *S*-transferase (GST) activity for UI Sparrow, Brundage 96 and UI Castle CL+ was performed using a spectrophotometer. Crop injury from safener would limit its use and so in the absence of herbicide, we set a threshold of 10% crop injury. Data analyses showed effective doses resulting in 10% biomass reduction due to fluxofenim-alone treatment ranged from 0.55 to 1.23 g ai kg^{-1} seed for the varieties. The experiment evaluating the response of three varieties to safener in the presence of herbicides showed effective doses resulting in 90% fluxofenim-enhanced tolerance to *S*-metolachlor ranged from 0.07 g ai kg^{-1} seed for UI Castle CL+ to 0.55 g ai kg^{-1} seed for Brundage 96 while effective doses resulting in 90% fluxofenim-enhanced tolerance to dimethenamid-P ranged from 0.09 g ai kg^{-1} seed for UI Sparrow to 0.73 g ai kg^{-1} seed for Brundage 96. Similar findings were observed for pyroxasulfone where effective doses resulting in 90% fluxofenim-enhanced tolerance ranged from 0.30 g ai kg^{-1} seed for UI Castle CL+ to 1.03 g ai kg^{-1} seed for Brundage 96. GST assay showed increased enzyme activity for the three varieties in the presence of safener. GST specific activity at 0.36, 0.91 and 1.96 g ai kg^{-1} seed treatments was not significantly different for Brundage 96 and UI Castle CL+ but differed for UI Sparrow. Results from these series of experiments suggest safener protected UI Sparrow, Brundage 96 and UI Castle CL+ from *S*-metolachlor, dimethenamid-P and pyroxasulfone injury at the herbicide rates tested. Further evaluation of safener protection of wheat varieties from VLCFA herbicide injury in the field could provide important insights into the use of VLCFA inhibitors for preemergence annual grass control in wheat.

***Cyperus difformis* ALS Cross-Resistance Levels and Target-site Characterization.** Alex R. Ceseski*, Kassim Al-Khatib; University of California, Davis, Davis, CA (324)

Populations of *Cyperus difformis* L. (smallflower umbrella sedge) resistant to the ALS inhibitor bensulfuron-methyl were discovered in California rice fields in 1994, four years after its release. Since then, *C. difformis* populations resistant to each ALS inhibitor registered for California rice have been identified. To adequately inform growers of their *C. difformis* management options, and inform the rice industry of the magnitude of the ALS resistance issue, a comprehensive characterization of the scale, distribution, and mechanisms of ALS inhibitor cross-resistance is required. Sixty-two populations of *C. difformis* suspected to be ALS inhibitor resistant were collected from throughout the California rice region and screened for ALS cross-resistance. Herbicides administered were bensulfuron-methyl, halosulfuron-methyl, bispyribac-sodium, and penoxsulam, applied at discriminating rates of 70.1 & 210.3, 70.1 & 210.3, 37.4 & 112.2, and 42 & 126g ha^{-1}, respectively, with a bench-type track sprayer calibrated to 187L ha^{-1}, with a single 8002EVS nozzle. Adjuvants were added per manufacturer recommendations. Six patterns of ALS cross-resistance were detected, and one *C. difformis* population from each resistance pattern was self-pollinated to S-1 generation. Resulting seed were tested for resistance levels via dose-response using were bensulfuron-methyl, halosulfuron-methyl, bispyribac-sodium, and penoxsulam, with rates ranging from 13.3-852, 13.3-852, 7.1-455, and 8-510g ai ha^{-1} respectively, administered in the same manner as above. Malathion inhibition of cytochrome P450s was utilized to detect evidence of enhanced metabolism as a mechanism of resistance. S-1 seed were sprayed with the abovementioned herbicides at 70.1, 70.1, 37.4, and 42 g ha^{-1}, respectively, either alone or with malathion administered at 1.5kg ha^{-1} 16h before and 6h after herbicide treatments. All treatments included 0.25% v/v nonionic surfactant (NIS). Screening revealed six major patterns of ALS inhibitor cross-resistance, with no apparent geographic distribution pattern. Each population tested was resistant to bensulfuron-methyl, with average survival of 75% at the lower rate. Twenty-one populations were susceptible to halosulfuron-methyl, even though it and bensulfuron-methyl are sulfonylureas. Only three populations showed resistance to penoxsulam; two were resistant to all four herbicides. Dose-response confirmed that the majority of resistance in the tested populations was dose-dependent, suggesting nontarget-site resistance mechanisms. Two populations showed high survival at the highest herbicide rates, with RI's >1000, and therefore may possess insensitive ALS enzymes. Malathion inhibition confirmed that P450s are involved with some ALS cross-resistance in these populations. Bensulfuron injury increased by 50 – 400% in most populations, with population r4 having a 75% decrease in injury, and SUS showing no change. Populations r18 and r59 had increases of bispyribac injury from 5 to 35% and from 3 to 62% , respectively. Penoxsulam injury increased in populations r18, r41, and r59 from 7 to 37%, 16 to 57%, and 45 to 61%, respectively. Malathion had no significant effect on halosulfuron injury. It is clear that multiple pathways of dose-dependent ALS inhibitor resistant are present in the study populations. Cytochrome P450s appear to only be involved in a portion of the resistance, though malathion may not antagonize all P450s. It may be possible that glutathione S-transferases or glucosyl transferase may also be involved in enhanced herbicide metabolism.

Simultaneous Overexpression of Three Cytochrome P450s is Involved in High Level Resistance to Diclofop-methyl in Multiple-herbicide Resistant Late Watergrass (*Echinochloa phyllopogon*). Hiroe Suda*[1], Yusuke Yoshimoto[1], Kohei Kurata[1], Keisuke Tanaka[2], Satoru Tanaka[2], Takuya Yamaguchi[3], Masahiro Miyashita[1], Tohru Tominaga[1], Satoshi Iwakami[1]; [1]Kyoto University, Kyoto, Japan, [2]Tokyo University of Agriculture, Tokyo, Japan, [3]University of Tsukuba, Tsukuba, Japan (325)

Populations of late watergrass (*Echinochloa phyllopogon)* from California have evolved resistance to multiple herbicides. Previous studies demonstrated that the multiple resistance was primarily caused by the overexpression of two cytochrome P450s, CYP81A12 and CYP81A21, that detoxify several herbicides including acetyl-CoA carboxylase (ACCase) inhibitors. However, the mechanism of high-level resistance to the ACCase inhibitor diclofop-methyl cannot be fully explained by the enhanced metabolism conferred by these P450s. To investigate the additional mechanism for diclofop-methyl resistance, diclofop metabolites formed in resistant and susceptible *E. phyllopogon* were analyzed using LC-MS/MS. Significant accumulations of two different putative hydroxylated diclofop (metabolites 1 and 2) were observed in the resistant line. Although their structures were unknown, metabolite 1 corresponded to the major metabolite formed by CYP81As in yeast expression system. RNA-Seq analysis identified 16 novel P450 genes highly expressed in the resistant line, six of which co-segregated with diclofop-methyl resistance in the F6 recombinant inbred lines. Among the six genes, only *EpP450-1* conferred resistance to diclofop-methyl and formed metabolite 2 in rice calli and yeast expression systems, respectively. Furthermore, the chemical structures of metabolites 1 and 2 were determined by NMR analysis. *CYP81A12*, *CYP81A21*, and *EpP450-1* were tightly co-expressed under various stress treatments. Altogether, our study indicates that the high-level resistance to diclofop-methyl in multiple-herbicide resistant *E. phyllopogon* is caused by simultaneous overexpression of these three P450 genes.

Herbicide-Resistance In Waterhemp (*Amaranthus tuberculatus*) Identified in Israel is Due to a Long Distance Gene Transfer. Inon Yadid, Zvi Peleg, Baruch Rubin*; The Hebrew University of Jerusalem, Rehovot, Israel (326)

Abstract not available

Candidate Mutations for Fluroxypyr Resistance in Kochia (*Bassia scoparia*) from Colorado. Olivia E. Todd*, Todd A. Gaines; Colorado State University, Fort Collins, CO (327)

The synthetic auxin fluroxypyr (Group 0/4) is used to control broadleaf weeds in grass systems. A fluroxypyr resistant population from eastern Colorado (flur-R) has been characterized with an LD50 of 494 g ae/ha fluroxypyr. Flur-R was 20-29x more resistant than two susceptible populations (9425 and J01-S), and does not display any auxin-related herbicide symptoms post-application. After several generations of bulk pollination, an RNA-seq experiment was performed on Flur-R, 9425, and J01-S. Differential expression analysis was conducted with DESeq2, and several non-target site candidate genes of interest have been identified after filtering for log2 fold change (LFC) > 2 and pvalue < 0.001. Expression candidate genes include cytochrome p450's, esterases, and ARF transcriptional protein upregulation. The program SnpEff was used for variant calling and has produced several target site candidates in Aux/IAAs and other auxin response-related proteins. More work is required to validate these candidate genes for a mechanistic role in fluroxypyr resistance.

A Non-destructive Leaf Disc Assay for Rapid Diagnosis of Weed Resistance to Multiple Herbicide Modes of Action. Chenxi Wu*[1], Vijaya Varanasi[1], Alejandro Perez-Jones[2]; [1]Bayer CropScience, St Louis, MO, [2]Bayer Crop Science, Chesterfield, MO (328)

Rapid diagnosis is very critical for monitoring weed resistance allowing actions proactively before dissemination, as well as enabling simultaneous phenotyping and genotyping of resistant weeds. As an alternative to the time-consuming and labor-intensive greenhouse herbicide screens, we here introduce a non-destructive leaf disc assay based on chlorophyll fluorescence (Fv/Fm test) for

rapid detection of resistance to both systemic and contact herbicides within 48h. Current study validated the prediction accuracies of the assay on detecting resistance to fomesafen, glyphosate, and dicamba in multiple weed species. Results showed Fv/Fm values negatively correlated with the spray injury levels and the correlation coefficients ($p<0.05$) at discriminating doses were -0.47 (*A. tuberculatus, A. palmeri)*, -0.92 (*E. indica)*, and -0.46 (*B. scoparia)* for fomesafen, glyphsoate and dicamba, respectively. On individual plant level, the assay yielded false negative/positive results across herbicides, with prediction accuracy rates of 82.9% (*A. tuberculatus, A. palmeri*, N=250), 85.0% (*E. indica*, N=80), and 82.6% (*B. scoparia* with and without a resistance endowing IAA16 mutation, N=46) fomesafen, glyphosate and dicamba, respectively. The assay was less effective on detecting glyphosate resistance in *A. tuberculatus* and *A. palmeri*, with a prediction accuracy rate of 46.7%. More research is needed to validate the sensitivity and expand the usage of the assay in distinguishing weed populations of different resistance levels, as well as different geographical origins and genetic basis.

Investigation of Physiological Mechanism of 2,4-D Resistance in Palmer Amaranth (*Amaranthus palmeri*). Chandrima Shyam*, Dallas E. Peterson, Mithila Jugulam; Kansas State University, Manhattan, KS (329)

Palmer amaranth is one of the most troublesome weeds throughout the US. The evolution of resistance to multiple herbicides in Palmer amaranth is a serious challenge for sustainable crop production. In 2018, a population of Palmer amaranth (Kansas Conservation Tillage Resistant = KCTR) was suspected to have evolved resistance to 2,4-D in Kansas. The objectives of this study were to i) conduct dose-response assay to evaluate the level of 2,4-D resistance in KCTR Palmer amaranth in comparison to two known Palmer amaranth susceptible populations i.e., S1 and S2, ii) perform [^{14}C] 2,4-D absorption, translocation and metabolism studies to investigate the physiological mechanism of resistance, and iii) using P450-inhibitor (malathion), assess potential involvement of cytochrome P450 (P450s) enzymes in imparting 2,4-D resistance. The dose-response study was carried out by treating 10-12 cm tall KCTR, S1 and S2 plants with varying doses of 2,4-D and repeated once. Absorption, translocation, and metabolism of 2,4-D were determined at 6, 24, 48 and 72 hours after treatment (HAT) using [^{14}C]2,4-D. The results of the dose-response study indicated that KCTR Palmer amaranth is 9-14 fold-resistant to 2,4-D relative to S1 or S2. Preliminary analysis of [^{14}C] 2,4-D absorption suggested no difference that can explain the resistance, although KCTR plants translocated less 2,4-D than S1 or S2. Importantly, 2,4-D (~35%) was detoxified markedly faster at 24 HAT in KCTR Palmer amaranth compared to sensitive plants. The use of malathion increased the sensitivity of KCTR Palmer amaranth resistance to 2,4-D, supporting detoxification of 2,4-D possibly by P450 activity. Overall, the results of this research suggest a predominance of non-target site resistance to 2,4-D in KCTR Palmer amaranth, although future research will investigate the presence of any target-site resistance mechanisms in this population.

Investigating Metabolic Resistance to S-Metolachlor in Two Illinois Waterhemp (*Amaranthus tuberculatus*) Populations. Seth A. Strom*[1], Aaron Hager[1], Nicholas J. Seiter[1], Adam Davis[1], Shiv S. Kaundun[2], Dean E. Riechers[1]; [1]University of Illinois, Urbana, IL, [2]Syngenta, Bracknell, United Kingdom (330)

S-metolachlor has been widely used in agronomic cropping systems to control annual grasses and small-seeded dicot weeds, such as waterhemp (*Amaranthus tuberculatus*), since its commercialization in the 1990s. Previously, we reported two multiple herbicide-resistant (MHR) waterhemp populations (SIR and CHR) from Illinois are resistant to *S*-metolachlor due to enhanced herbicide metabolism, relative to sensitive populations (ACR and WUS), using thin-layer chromatography. Radiolabeled *S*-metolachlor was utilized to further investigate the rate of metabolism in CHR and SIR in comparison to sensitive waterhemp and corn utilizing high-performance liquid chromatography (HPLC). Times to degrade 50% (DT_{50}) and 90% (DT_{90}) of absorbed *S*-metolachlor in CHR and SIR were shorter than either sensitive waterhemp population but equal to corn. Calculated DT_{90} values for CHR, SIR, and corn are 3.2, 2.7, and 2.7 hours, respectively, but exceeded six hours for WUS or ACR. HPLC experiments also revealed that metabolite profiles in CHR and SIR differ from sensitive waterhemp or corn. *S*-metolachlor metabolism in the presence of metabolic inhibitors was investigated using the glutathione *S*-transferase inhibitor, 4-chloro-7-nitrobenzofurazon (NBD-Cl), and cytochrome P450 inhibitor, malathion, applied alone or in combination. Both inhibitors reduced *S*-metolachlor metabolism in resistant populations. Conversely, only NBD-Cl reduced metabolism in sensitive waterhemp, but neither inhibitor affected metabolism in corn. In summary, results from HPLC and metabolic inhibitor experiments demonstrate that resistance to *S*-metolachlor in waterhemp is due to enhanced metabolism, and indicate that metabolic mechanism(s) in CHR and SIR are either different or more intricate than in sensitive waterhemp or corn. Research is underway to further quantify and identify initial metabolites formed using mass spectrometry and investigate the putative enzyme(s) and metabolic pathway(s) involved in *S*-metolachlor detoxification in waterhemp.

A New Understanding on the Mechanism of Action of Glufosinate. Franck E. Dayan*[1], Roland S. Beffa[2], Christopher Preston[3], Philip Westra[1], Hudson K. Takano[1]; [1]Colorado State University, Fort Collins, CO, [2]Bayer AG, CropScience Division, Frankfurt, Germany, [3]University of Adelaide, Glen Osmond, Australia (331)

Glufosinate is a potent inhibitor of glutamine synthetase (GS), a key enzyme for nitrogen and amino acid metabolism. Yet, its fast-acting contact activity is unlike other amino acid biosynthesis inhibitors. An in-depth investigation on its mechanism of action revealed that the rapid herbicidal action is triggered by a massive accumulation of reactive oxygen species (ROS). The relationship between GS inhibition and ROS accumulation was investigated in *Amaranthus palmeri*. Glufosinate fast action is light-dependent with no visual symptoms or ROS formation in the dark. Inhibition of GS leads to accumulation of ammonia and several intermediates of the photorespiration pathway, such as glycolate and glyoxylate, as well as depletion of other intermediates such as glycine, serine, hydroxypyruvate and glycerate. Exogenous supply of glycolate to glufosinate-treated plants enhanced herbicidal activity and dramatically increased hydrogen peroxide accumulation (possibly from peroxisomal glycolate oxidase activity). Glufosinate affects the balance between ROS generation and scavenging. The activity of superoxide dismutase, catalase, ascorbate peroxidase and glutathione reductase increased after glufosinate treatment in an attempt to quench the nascent ROS burst. Low doses of atrazine and dinoseb were used to investigate the sources of ROS by manipulating photosynthetic electron transport. ROS formation depended on electron flow inhibition and oxygen evolution from photosystem II (PSII). Inhibition of GS blocks photorespiration, carbon assimilation and linear electron flow in the light reactions. Consequently, the excess of electrons is accepted by molecular oxygen produced from the splitting of water in PSII and generates a large amount of ROS which leads to lipid peroxidation and form the basis for the fast action of glufosinate.

A Biochemical Approach to Improve the Efficacy of Glufosinate. Hudson K. Takano*[1], Roland S. Beffa[2], Christopher Preston[3], Philip Westra[1], Franck E. Dayan[1]; [1]Colorado State University, Fort Collins, CO, [2]Bayer AG, CropScience Division, Frankfurt, Germany, [3]University of Adelaide, Glen Osmond, Australia (332)

Glufosinate inhibits glutamine synthetase (GS), a key enzyme for amino acid metabolism and photorespiration. Protoporphyrinogen oxidase (PPO) inhibitors block chlorophyll biosynthesis and cause protoporphyrin accumulation, which is lethal to plants. Both herbicides are toxic to plants by the accumulation of reactive oxygen species (ROS). We investigated a potential synergistic effect when these two herbicides are applied in combination. The association of glufosinate (280 g ha^{-1}) with low dose of saflufenacil (1 g ha^{-1}) resulted in enhanced herbicidal activity compared to the products applied individually. The isobole analysis also indicated that these two herbicides synergize each other. Similar results were observed with low rates of other PPO inhibitors (lactofen, pyraflufen-ethyl, flumioxazin and fomesafen). The inhibition of GS by glufosinate leads to a transient accumulation of glutamate. This routes the excess glutamate toward chlorophyll biosynthesis (each chlorophyll molecule is comprised of 8 glutamate molecules). Consequently, the herbicide combination results in greater accumulation of protoporphyrin and ROS compared to the products applied individually. Therefore, glufosinate enhances the activity of PPO inhibitors through glutamate and protoporphyrin accumulation, leading to increased levels of ROS and lipid peroxidation. The synergism between the two herbicide groups may help to overcome the environmental effects on glufosinate efficacy.

Role of Epigenetics Modifications in the Development of Herbicide Resistance. Gourav Sharma*, Jacob Barney, Shawn Askew, James Westwood, David Haak, Suzanne Laliberte, Liqing Zhang; Virginia Tech, Blacksburg, VA (455)

Herbicide resistance is the result of a powerful human-driven selective pressure on weeds. Two general categories of resistance are target site resistance (TSR) and non-target site resistance (NTSR). TSR mechanisms are well understood and arise from a single point mutation in the herbicide target gene, but those involving NTSR are still poorly understood and could result from several mechanisms. The origin and genetic bases for NTSR resistance mechanisms is not known. The field of epigenetics may contribute to understanding NTSR in that it contributes to understanding how organisms are able to adapt to various abiotic/biotic stresses through non-sequence based modifications of their DNA, such as changes in methylation status or histone assembly. Herbicides and other control practices impose stress on weeds. Sub-lethal weed management practices could lead to epigenetic modifications that may facilitate evolution of resistance, but this relationship is yet untested. DNA methylation is one of the best-studied epigenetic regulatory mechanismss, which is the addition of a methyl group to. Adding or removing methyl groups to cytosine nucleotides in specific DNA regions can change gene expression. Using the model plant *Arabidopsis thaliana*, we administered sub-lethal doses of glyphosate, trifloxysulfuron, clipping and shading to determine if methylome changes are shared or unique among stress responses. Methylation occurs in all cytosine sequence contexts of plant DNA: CG, CHG and CHH (H represents A, T or C). The tissues from control and stressed plants were collected at standardized maturation levels and subjected to whole-genome, bisulfite sequencing (WGBS). The WGBS data were analyzed to understand how different stresses change the cytosine methylation levels. The total amount of methylated cytosines (mCs) ranged from 98 to 147 million depending on stress and were the most abundant in the CG sequence context. Neither the abundance nor frequency of methylated mCs in CG, CHG, and CHH contexts varied due to stress treatment. These results suggest that plants respond similarly to herbicides, clipping, and shade with respect to total methylation levels. DNA hypomethylation refers to the loss of the methyl group in the 5-methylcytosine nucleotide, whereas hypermethylation refers to the addition of the methyl group. The gain and loss of the methyl group can change the gene expression. Glyphosate have highest differential hypermethylated sites (9375), whereas clipping (50) have the lowest. On the contrary, clipping (268) have the highest differentially hypomethyled sites and glyphosate (50) have the lowest. Further analyses will elucidate how methylation patterns are influenced by stress treatment and if these patterns are heritable and stable across multiple generations in *A. Thaliana*.

A Characterization of Tissue Specific Alpha-Tubulin Gene Expression Two Grass Species, Annual Bluegrass (*Poa annua*) and Finger Millet (*Eleusine coracana*). Nathan D. Hall*, Jinesh D. Patel, Eli C. Russell, James Harris, Leslie R. Goertzen, Joseph S. McElroy; Auburn University, Auburn, AL (456)

Alpha-tubulin is a highly conserved protein and may be encoded by several different loci that exhibit signs of tissue specific expression. Here, we offer practical reminders about the study of *alpha-tubulin* genes possessing target site mutations. Angiosperms often maintain several functional *alpha-tubulin* loci which are the result of copies retained after whole genome duplication events and subsequent subfunctionalization. These copies, despite showing signs of differential expression, often all contribute to standing pools of available Alpha-tubulin within the cell at any given time. Using developing genomic systems, finger millet (*Eleusine coracana* L. Gaertn.) and annual bluegrass (*Poa annua* L.), we demonstrate that *alpha-tubulin* expression is variable and that herbicide resistant mutations are not limited to a single locus. To examine subfunctionalization within the context of an allotetraploid, we mapped several publicly available RNA-seq data sets to a phased finger millet genome, and quantified *alpha-tubulin* expression using ht-seq. Finger millet exhibits typical subfunctionalization of at least 6 distinct copies of *alpha-tubulin*. *Alpha-tubulin* expression is dominated by single clade with a distinct B genome bias across nearly all samples examined. To examine broad patterns of expression within annual bluegrass, qPCR was run on all *alpha-tubulin* loci in susceptible and resistant plants. We used vector cloning to characterize resistant *alpha-tubulin* loci and to determine if resistance was limited to a single clade of *alpha-tubulin*. Annual bluegrass shows a pattern of highly expressed *alpha-tubulin* within herbicide resistant populations, and target site mutations at 2 different loci, as determined through alignment to the annual bluegrass transcriptome, suggesting the recurrent evolution of herbicide resistance is not limited to one specific locus and that all loci should be sampled to determine if target site resistance is present.

Establishing a Basis for 2,4-D Tolerance in Red Clover (*Trifolium pratense*): RNA-seq Analysis of Susceptible and Tolerant Cultivars Following 2,4-D Application. Lucas Araujo*[1], Michael Barrett[1], Randy Dinkins[2], Linda D. Williams[1], Troy Bass[2]; [1]University of Kentucky, Lexington, KY, [2]USDA/FAPRU, Lexington, KY (457)

Incorporation of red clover (*Trifolium pratense*) into grass pastures offers several benefits. However, red clover cultivars that are available for Kentucky producers are highly susceptible to herbicides. The lack of a selective herbicide that does not injury the red clover presents a considerable limitation to the management of broadleaf weed species in interseeded clover-grass pastures. A novel Kentucky red clover cultivar, UK2014, expresses increased tolerance to the herbicide 2,4-D. As 2,4-D has been the standard for broadleaf weed control in pastures, adopting UK2014 would expand the weed management options in clover-grass systems.To investigate the increased 2,4-D tolerance in UK2014 we employed a transcriptome analysis approach. UK2014 was compared with a 2,4-D sensitive Kentucky cultivar, Kenland. Leaf tissue from both cultivars was sampled at 4, 24, and 72 hours after treatment (HAT) from untreated and treated (2.24 kg 2,4-D Amine a.e. ha^{-1}) red clover plots. Global gene expression in samples was determined with reads from Illumina Hiseq 2500 mapped against the red clover draft genome. Annotations for the clover reference genome were obtained from a multi-BLASTX query against predicted proteins of *Medicago truncatula* and *Arabidopsis thaliana*. Contigs that displayed differential expression due to 2,4-D treatment, within cultivar across time and at specific time points, were selected for further analysis. Gene ontology enrichment analysis of the differentially expressed terms was performed with the AgriGO toolkit. Overall, the expression level of UK2014 and Kenland was similar across time points. The majority of differential expression due to 2,4-D treatment occurred at 24 HAT in both cultivars. Interestingly, the susceptible cultivar enriched GO terms associated with oxidoreductases and transferases activities whereas these terms were less enriched in the tolerant cultivar. Regarding metabolism gene families, more contigs with P450 annotations were upregulated in the susceptible cultivar than in the tolerant, especially at 4 HAT. Nonetheless, both cultivars presented metabolism-related genes upregulation. In general, the susceptible cultivar Kenland upregulated more of the early-response auxin genes, such as NCED, GH3, and ACC synthase. Further research, including pathway analysis and identification of putative 2,4-D tolerance genes, is necessary to elucidate the differential response between cultivars.

Mechanisms of 2,4-D Resistance in Palmer Amaranth. Wendy A. Peer*; University of Maryland, College Park, MD (458)

Abstract not available

Investigation of Lactofen Resistance in a Population of *Amaranthus palmeri*. Jacob S. Montgomery*, Darci A. Giacomini, Patrick Tranel; University of Illinois, Urbana, IL (459)

During the 2017 growing season, samples of Palmer amaranth (*Amaranthus palmeri*) that had reportedly survived field-rate applications of lactofen were collected from the Midwest and tested for target-site mutations known at the time to convey resistance to protoporphyrinogen-oxidase

(PPO)-inhibiting herbicides. One population (W-8) tested negatively for all such mutations, leading to further investigation of this population. Seeds from the sampled field were germinated and plants were confirmed to be resistant to lactofen, with an R:S ratio comparable to that conferred by the deletion of a glycine residue at the 210th amino acid position of protoporphyrinogen-oxidase II (PPX2). Gene sequences from W-8 PPX2 were compared to sequences of known PPO-inhibitor-sensitive PPX2, and a glycine to alanine substitution at the 399th amino acid position, subsequently shown to reduce target-site sensitivity, was noted in a subset of the resistant plants. Because no missense mutation completely delimited R and S populations, we suspected that there was a secondary, non-target-site resistance mechanism in this population. To isolate the two mechanisms, a segregating F_2 population was produced and screened with a delimiting rate. A Chi-Square analysis of dead/alive ratings indicated single locus inheritance of resistance in the F_2 population, and molecular markers for the W-8 parental PPX2 coding region co-segregated tightly but not completely with resistance. Future work will include crossing homozygous G399A plants and evaluating this isolated target-site resistance mechanism in comparison to the secondary resistance mechanism in W-8 and to other known resistance mechanisms.

Integrating UPLC-qTOF-MS and UPLC-MS/MS to Characterize Resistance to Bentazon in *Chenopodium album* L. Populations from Oregon. Lucas Baiochi Riboldi*, Ed Peachey, Andrew G. Hulting, Caio A. Brunharo; Oregon State University, Corvallis, OR (460)

A bentazon-resistant commom lambsquarters (*Chenopodium album* L.) biotype was recently identified in the Willamette Valley in Oregon. Our preliminary research suggests that bentazon resistance is likely conferred by enhanced herbicide metabolism mediated by cytochrome P450 enzymes. We developed a method to extract, detect, and analyze these compounds from the bentazon-resistant and -susceptible common lambsquarters tissue. A total of 50 µL of bentazon was applied to the adaxial leaf surfaces in small droplets of herbicide solution. Plant samples were collected at 0, 3, 6, 12, 24, 48, 72 hours after herbicide application. Plants were quickly rinsed just before sampling to remove non-absorbed herbicide. Plant tissue was ground in liquid nitrogen followed by a 100% methanol extraction. Bentazon-d7 was used as internal standard. Ultra-high-performance liquid chromatography coupled to quadrupole time-of-flight mass spectrometry (UHPLC/ToF-MS/MS) and liquid chromatography mass spectrometry (LC-MS/MS) were used to identify bentazon and its metabolites. Our methodology was able to extract and identify the parent compound bentazon, internal standard bentazon-d7 and chemical compounds with masses similar to hydroxy-bentazon and glucose-bentazon, known bentazon metabolites in other plant species. No differences in herbicide absorption between resistant and susceptible biotypes were observed. Maximum absorption and bentazon recovery was identified between 6-12 hours after treatment. We also observed additional unidentified metabolites that may play a role in the mechanism of bentazon resistance. UHPLC/ToF-MS/MS results suggest that metabolic profile of bentazon-resistant and -susceptible common lambsquarters differed.

QTL Discovery for Resistance to HPPD Inhibitors in *Amaranthus tuberculatus*. Brent P. Murphy*, Patrick Tranel; University of Illinois, Urbana, IL (461)

Waterhemp (*Amaranthus tuberculatus*) is a predominant driver weed within production agriculture of the Midwestern United States. Herbicide resistance is a major and growing issue within the species, which has resistance to herbicides encompassing seven sites of action, including inhibitors of 4-hydroxyphenylpyruvate dioxygenase (HPPD). In contrast to target-site resistance, characterization of non-target-site resistance often requires non-targeted approaches. With the recent release of a high-quality genome assembly for waterhemp, genomics approaches to the investigation of non-target-site herbicide resistance in this species are now practical. HPPD-inhibitor resistance within a Nebraskan waterhemp population was characterized at the phenotypic and genomic levels. A biparental QTL mapping population was established from paired plant crosses. Resistance was dominant within the F_1 generation, and appeared multigenic within the segregating pseudo-F_2 generation. Double-digest restriction-associated DNA sequencing was conducted on the segregating pseudo-F_2 population. Bulk segregant analysis revealed five QTL which underlay HPPD-inhibitor resistance in the Nebraska population. Molecular markers specific to each QTL were developed to validate the QTLs to the observed resistance phenotype.

Modes of Action of Two Natural Herbicides in the Bioherbicide MBI-014. Stephen O. Duke*[1], Franck E. Dayan[2], Louis G. Boddy[3], Zhiqiang Pan[4], Joanna Basja-Hirschel[4]; [1]University of Mississippi, Oxford, MS, [2]Colorado State University, Fort Collins, CO, [3]Marrone BIo Innovations, Davis, CA, [4]USDA- ARS, Oxford, MS (462)

MBI-014 is a new microbial herbicide derived from the soil microbe *Burkholderia rinojensis* strain A396 that is active on many weeds and is especially effective on *Amaranthus* species. Its activity is substantially due to two phytotoxins, the a cyclodepsipeptide (MW540) and spliceostatin C (SpC). MW540 was highly phytotoxic to Arabidopsis, with an IC_{50} of 0.18 µM. MW540 was found to inhibit histone deacetylases. The activity was greater when its macrocyclic-forming disulfide bridge was chemically reduced to liberate a highly reactive free butenyl thiol side chain. A similar bioactivation of the proherbicide via reduction of the disulfide bridge of MW540 was observed in plant cell-free extracts, indicating that is bioactivated *in vivo*. Molecular dynamic simulation of the binding of MW540 to *Arabidopsis thaliana* histone deacetylase protein indicated the reduced form of the compound could reach deep inside the catalytic domain and interact with an associated zinc atom required for enzyme activity. SpC alone significantly inhibited the growth of *Arabidopsis thaliana* seedlings with an IC_{50} concentration of 2.2 µM. Arabidopsis seedlings were treated with the IC_{50} concentration, and mRNAs were extracted for semiquantitative RT-PCR (RT-sqPCR) analysis of 20 genes, in which intronless genes, regulation factors, and stably expressed genes were included. SpC modified both constitutive and alternative mRNA splicing. Five transcripts underwent intron rearrangements such as intron retention and alternative 5? or 3? splicing site, resulting in additional and longer transcripts. The expression levels of the rest of the genes were either increased or decreased significantly. Global proteome profiling reductions revealed that 90% of the proteins significantly affected after 6 h of treatment were reduced, and 10% were increased. In silico binding studies indicated that SpC interacts with SF3b proteins belong to the U2 snRNA sub-complex of the spliceosome. Significant contribution to the herbicidal activity of MBI-014 by two phytotoxins with very different chemical structures and each with a novel target site provides the chemical structure and mode of action diversity needed for both target-site and non-target-site resistance management in one product.

Resistance to a Non-Selective HPPD-Inhibiting Herbicide in Multiple-Resistant Waterhemp (*Amaranthus tuberculatus*) Populations. Jeanaflor Crystal Concepcion[1], Sarah-Jane Hutchings[2], James Morris[2], Shiv S. Kaundun[2], Anatoli V. Lygin[1], Dean E. Riechers*[1]; [1]University of Illinois, Urbana, IL, [2]Syngenta, Bracknell, United Kingdom (463)

Waterhemp is an annual dicot weed that has evolved resistance to several commercial herbicides inhibiting the 4-hydroxyphenylpyruvate dioxygenase (HPPD) enzyme. Previous HPPD-inhibitor resistance mechanism studies using mesotrione and tembotrione (both triketones) or topramezone (pyrazole) demonstrated that rapid oxidative metabolism of the parent compound confers resistance in multiple herbicide-resistant (MHR) waterhemp populations. In the current study, we investigated resistance mechanism(s) for a presumably metabolically blocked, non-selective HPPD-inhibiting herbicide called syncarpic acid-3 (SA3) in two MHR populations compared with two HPPD inhibitor-sensitive populations. Our first research objective was to determine if the two MHR waterhemp populations (SIR and NEB) metabolize SA3 more rapidly than two sensitive populations (ACR and SEN). Our second objective was to identify the structure of any compounds formed during SA3 metabolism in waterhemp. An excised leaf assay measured rates of unlabeled SA3 metabolism during a 16-hour time course by extracting and quantifying SA3 levels via HPLC-photodiode array detection. The SIR and NEB populations exhibited faster rates of SA3 metabolism, particularly at 12 and 16 hours after treatment (HAT), compared to both ACR and SEN. The least amount of parent SA3 was quantified in excised SIR leaves at all time points and among all waterhemp populations tested, and corn leaves did not metabolize SA3 to an appreciable extent. Multivariate statistical analysis of more than 2000 compounds identified by LC-MS revealed several characteristic compounds unique to SA3-treated MHR waterhemp leaves, including putative polar metabolites of SA3 at each time point examined. Among the most interesting and discriminatory metabolites was a putative hydroxy-SA3 (M+16) metabolite that was more abundant in SIR than ACR leaves. Further work to characterize the metabolites formed in SA3-treated leaves at 12, 24, and 48 HAT using LC-MS/MS will be aimed at identifying metabolite chemical structures, ascertaining sites susceptible to metabolism, and deducing possible metabolic enzymes involved in SA3 detoxification reactions in MHR waterhemp.

The Transcriptional Landscape of Glyphosate Resistance in Palmer Amaranth (*Amaranthus palmeri*): More Than EPSPS Gene Amplification. William T. Molin*[1], Christopher A. Saski[2]; [1]USDA-ARS, Stoneville, MS, [2]Clemson University, Clemson, SC (464)

Paper withdrawn

Progress in the Characterization of CYPs and GSTs Involved in Weed Resistance to Herbicides. Functional Validation. Roland S. Beffa*; Bayer AG, CropScience Division, Frankfurt, Germany (465)

Sustainable agriculture is depending on weed control which includes the use of herbicides in combination to non-chemical tools in an Integrated Weed Management strategy. Nevertheless, the continuous use of herbicides since decades has led to the evolution of different resistance mechanisms grouped into Target-Site Resistance (TSR) and Non-Target-Site Resistance (NTSR). TSR is related to the Mode / Site of action (MoA) of the herbicides, whereas NTSR is related to the herbicide chemical structure. NTSR is an important threat because it can confer resistance to a broad-range of herbicides with different MoAs. One particularly important NTSR mechanism is the detoxification of the herbicides known as Enhanced Metabolic Resistance (EMR). The molecular and biochemical mechanisms involved in EMR are still poorly understood. Recent genomic studies have contributed to better understand EMR. Data related to EMR characterization in different weed species both monocotyledonous and dicotyledonous (e.g. *Lolium* spp., *Alopecurus myosuroides*, *Echinochloa* spp, or *Amaranthus* spp.) resistant to herbicides belonging to different groups (e.g. 1, 2, 15, and 27) showed that different Cytochrome P450s (Cyps) and different glutathione transferases (GSTs) can detoxify the same herbicides in weed populations from the same species or from different species. It can be shown also that the same Cyp or GST can detoxify herbicides having different MoAs. In addition to the increase understanding of the molecular mechanisms involved in EMR, this ask a question about the present herbicide classification based on MoAs which can help to select herbicides with a different MoA facing TSR. This cannot be used when EMR occurs. The need to define an herbicide classification based on genes involved in herbicide detoxification will be discussed.

WSSA SECTION 13: INTEGRATED WEED MANAGEMENT

Multiple Modes of Selection Prove Successful in Managing Horseweed (*Erigeron canadensis* L.). Theodore R. Vanhie*[1], Michael Cowbrough[2], Clarence Swanton[3], Francois Tardif[1]; [1]University of Guelph, Guelph, ON, Canada, [2]Ontario Ministry of Agriculture, Food and Rural Affairs, Guelph, ON, Canada, [3]University of Guelph, Guelph, AZ, Canada (466)

Developing strategies to control glyphosate-resistant horseweed (*Erigeron canadensis* L.) requires an integrated approach that utilizes multiple modes of selection that exceed the sole use of chemical control methods. Managing herbicide-resistant horseweed is proving difficult as farmers have a limited selection of management strategies available. This is especially true for soybean growers, to whom horseweed poses the greatest threat. In fields where this weed is left uncontrolled soybean yields can be decreased over 90%. Research trials were conducted in southern Ontario, replicated over the 2018 and 2019 growing seasons to evaluate the efficacy of three different selection pressures to control horseweed; these included rye (*Secale cereale* L.) cover crops, shallow tillage and herbicides. The results demonstrated when rye was used as a sole treatment, the cover crop managed to reduce the height of the weed by 61% and 88% in 2018 and 2019, respectively. Furthermore, rye decreased the biomass of the horseweed's population by 96% and 94% compared to the untreated check, in both seasons. Shallow tillage was inconsistent in controlling this weed. Tillage reduced the biomass of horseweed by 100% in the first season, while in 2019, tillage had no effect. Regarding herbicide treatments, the 600 g ae ha^{-1} rate of dicamba (3,6-dichloro-2-methoxybenzoic acid) and the 74.8 and 101.1 g ai ha^{-1} rates of saflufenacil (2-chloro-5-[3,6-dihydro-3-methyl-2,6-dioxo-4-(trifluoromethyl)-1(2H)-pyrimidinyl[-4-fluoro-N-[[methyl(1-methylethyl)amino] sulfonyl]benzamide) were consistent, providing =99% reduction of horseweed biomass, compared to the untreated check, in both years. No significant interactions between rye by tillage, rye by herbicides, or herbicides by tillage were consistent across the two years of study. The results of this research demonstrate rye and herbicides were effective in controlling horseweed; tillage did not provide consistent control. The role of multiple selection pressures proved beneficial in controlling horseweed. The observed interactions and effectiveness of each selection pressure varied between years.

Pollen Swamping Population Management Possibilities for Waterhemp (*Amaranthus tuberculatus*) Simulated *in silico*. Brendan C. Alexander*, Patrick Tranel, Aaron Hager, Nicolas F. Martin, Adam Davis; University of Illinois, Urbana, IL (467)

The evolution of resistance to weed control methods remains a critical problem in agriculture. Current recommendations from integrated weed management are to use diverse tank mixes and tactics to slow the evolution of resistance to any one method of control. However, the problem is still a numbers game and it is sensible to assume that weed populations will eventually develop resistance to current weed control tactics. Here we simulate some unorthodox methods of weed population control that could work specifically for dioecious species such as waterhemp. Our results indicate that sensitive allele swamping with pollen or seeds has the putative effects of reducing population size along with herbicide resistance. Swamping with sterile pollen or using a gene-drive system that promotes the propagation of males relative to females may result in population control only. These simulations can be used to inform new tactics for combating some weed species.

Unexpected Resistance Evolution to a Carotenoid Biosynthesis Inhibiting Herbicide in Field Selected Cross Resistant Rigid Ryegrass (*Lolium rigidum*) Populations from Australia. David J. Brunton*[1], Peter Boutsalis[2], Gurjeet Gill[2], Christopher Preston[2]; [1]University of Adelaide, Adelaide, Australia, [2]The University of Adelaide, Adelaide, Australia (468)

Resistance evolution in *L. rigidum* in Australia has been reported to the pre-plant incorporated (PPI) herbicides trifluralin Group 3[(K1)]; inhibitors of microtubule polymerization, prosulfocarb Group 8[(N)]; inhibitors of fatty acid elongation and pyroxasulfone Group 15[(K3)]; inhibitors of very-long-chain fatty-acid synthesis. Cross-resistance to these herbicides has been reported in multiple field-selected *L. rigidum* populations from across southern Australia and has significantly limited the available herbicides for its control in wheat. Bixlozone [Group 13[(F4)]; inhibitors of carotenoid biosynthesis] is a new PPI herbicide (isoxazolidinone family) to be registered in Australia in 2021. The susceptible *L. rigidum* population SLR4 was completely controlled at 40 g ai ha^{-1}. Three cross resistant *L. rigidum* populations (EP162, 375-14 and 198-15) showed LD_{50} of 108, 254 and 424 g ai ha^{-1} respectively to bixlozone. This corresponded to resistance index (RI) 2.7, 6.4 and 10.6-fold greater than the susceptible. *L. rigidum* individuals that survived a full herbicide dose were crossed and exposed to further testing. Screening of the first generation (F_1) survivors showed a significant shift in LD_{50} to 311 g ai ha^{-1} in EP162, 374 g ai ha^{-1} in 375-14 and 758 g ai ha^{-1} for 198-15 or a RI 7.8, 9.3 and 18.9-fold greater than the susceptible. This study reports the first case of field-evolved resistance in *L. rigidum* to the isoxalolidinone herbicide bixlozone, highlighting the rapid evolution of resistance to new site-of-action herbicides.

Present Status and Future Strategies for the Management of Herbicide Resistant Weeds of Wheat in India. Samunder Singh*; CCS HAU Hisar, Hisar, India (469)

After the onset of herbicide resistance in *Phalaris minor* in 1992; several weeds have evolved resistant to herbicides of multiple sites of action making it more difficult for the farmers to manage resistant weed species. Most of the available herbicides (isoproturon, fenoxaprop, clodinafop, pinoxaden, sulfosulfuron, mesosulfuron + iodosulfuron) have failed in managing multiple herbicide resistant *P. minor*. Resistance has also been confirmed in *Avena ludoviciana* to clodinafop, fenoxaprop, sulfosulfuron, clodinafop + metribuzin and pinoxaden); *Polypogon monspeliensis* (sulfosulfuron, and mesosulfuron + iodosulfuron); *Rumex dentatus* and *Chenopodium album* (metsulfuron-methyl, sulfosulfuron, sulfosulfuron + metsulfuron, mesosulfuron + iodosulfuron, carfentrazone). This sudden spurt in resistant weeds and the absence of an effective new herbicide molecule has made weed management most challenging. An integrated approach using weed biology, agronomical practices, chemical, mechanical and biological methods is evaluated for effective weed control. Herbicides have become an integral part of any control measure and in the absence of a new site of action molecule, there is need to fall back on old chemistry, using mixtures and their sequential application. Studies conducted in Haryana State using various combinations and sequences have provided good control of resistant *P. minor*, A. ludoviciana populations and other resistant weed species; however none of the herbicides alone was satisfactory, thus increasing the cost significantly. Pendimethalin PRE alone or mixed with metribuzin/pyroxasulfone/flufenacet followed by POE pinoxaden, sulfosulfuron, Atlantis, clodinafop + metribuzin, fenoxaprop + metribuzin, and three way mixtures (aclonifen + diflufenican + pyroxasulfone) provided effective control. Isoproturon that was earlier banned due to overwhelming resistance in *P. minor* is coming back for its effective control of *C. album*, *P. monspeliensis*, *R. dentatus* and even increased efficacy on *P. minor* and *A. ludoviciana* when mixed with P450 inhibitors. A rapid screening test developed using seed and seedling is very helpful in selecting sequential partner, but the same is not available to famers' and requires a better solution. Wheat seed treatment with *Bacillus subtilis* and *Providentia rettgeri* spp. not only improved wheat growth compared to untreated, but also lowered herbicide toxicity; the results on *P. minor*; however, were inconsistent. New effective herbicide molecules are required under an integrated system for sustainable weed management.

Long-term Muti-tactic Herbicide Resistance Weed Management. Steven B. Mirsky*[1], Lovreet S. Shergill[2], Mark VanGessel[3], Jason K. Norsworthy[4], Adam Davis[5]; [1]USDA-ARS, Beltsville, MD, [2]USDA-ARS & University of Delaware, Beltsville, MD, [3]University of Delaware, Georgetown, DE, [4]University of Arkansas, Fayetteville, AR, [5]University of Illinois, Urbana, IL (470)

Multiple herbicide-resistant (MHR) weeds are challenging sustainable crop production as herbicides are rapidly becoming less effective and herbicide discovery has slowed. To manage MHR weeds successfully, farmers need to employ multiple control tactics within the long term IWM approach. One promising tactic for managing MHR weeds is Harvest-time Weed Seed Control (HWSC), in which weed seeds are removed/destroyed at harvest time to reduce soil seedbank. Reducing weed seed return to the soil seedbank can be accomplished by various means, including chaff carts, narrow windrows, and Harrington Seed Destructor (HSD). HWSC is unlikely to be reliable as a stand-alone solution to herbicide resistance, rather most likely to be useful as part of an IWM system that includes chemical and cultural tactics that target multiple weed life stages at different points in the crop production cycle. Therefore, studies were conducted to evaluate the potential for IWM systems such as HWSC, herbicides, and cover crops to manage MHR weed populations. The results showed that late termination timing aids in greater accumulation of cereal rye biomass in both corn and soybean rotation. During all years, greater weed suppression was observed with later termination of cereal rye. The use of HSD in the soybean phase of corn-soybean rotation resulted in lower *Amaranthus hybridus* plant density in the corn phase. Corn and soybean yield were not significantly affected by cereal rye termination.

The Western IPM Kochia Work Group: Update and Next Steps. Todd A. Gaines*[1], Charles M. Geddes[2], Philip Westra[1], Kelly Bennett[3], Cody F. Creech[4], Rory Degenhardt[5], Mithila Jugulam[6], Rand Merchant[7], Sarah Morran[1], Olivia E. Todd[1]; [1]Colorado State University, Fort Collins, CO, [2]Agriculture and Agri-Food Canada, Lethbridge, AB, Canada, [3]Corteva Agriscience Canada, Calgary, AB, Canada, [4]University of Nebraska-Lincoln, Scottsbluff, NE, [5]Affiliation Not Specified, Edmonton, AB, Canada, [6]Kansas State University, Manhattan, KS, [7]BASF, Greeley, CO (471)

Kochia [*Bassia scoparia* (L.) A.J.Scott] is a problematic weed in cropped and non-cropped areas throughout western Canada and the United States. Prolific seed production, a short-lived seedbank, high genetic variability, pollen- and seed-mediated gene flow, phenotypic plasticity, and tolerance to drought, salinity, and cold temperatures make this weed an ideal candidate for the evolution of herbicide resistance. Separate kochia populations have been confirmed resistant to photosystem II inhibitors (Kansas, Idaho and Iowa in 1976; not present in Canada), acetolactate synthase inhibitors (Kansas in 1987; 1988 in Canada), synthetic auxins (Montana in 1994; 2015 in Canada), and glyphosate (Kansas in 2007; 2011 in Canada). Multiple resistance in kochia is present in Canada (three-way resistance) and the United States (four-way resistance), and reports of herbicide resistance in kochia are increasing rapidly. Growers have expressed concern regarding lack of kochia control and the lack of other management tools which are effective for kochia management. The North American Kochia Work Group was established following the initial meetings of the Kochia Action Committee at the 2017 Global Herbicide Resistance Challenge Meeting in Denver, CO and the 2018 Western Society of Weed Science Meeting in Garden Grove, CA. The North American Kochia Work Group Executive Committee planned the first in-person meeting of the Kochia Work Group hosted in Denver, CO on October 16-17, 2019. Over forty academic and government researchers, industry representatives, and local farmers attended the meeting, which included forward-thinking presentations and discussion on kochia knowledge-gaps and research priorities. The research priorities were ranked by attendees and targeted research teams were established. The North American Kochia Work Group aims to develop a coordinated research strategy to improve knowledge of kochia biology, ecology and management, awareness of herbicide resistance, and adoption of beneficial management practices of farms in North America.

Efficacy of Cotton and Peanut Residual Herbicides in High Residue Cover Crop System. Katilyn J. Price*, Steve Li, Frances B. Browne, Ryan D. Langemeier; Auburn University, Auburn, AL (472)

As herbicide resistant weeds continue to emerge and spread, alternative non-chemical control methods integrated into current control programs need to be evaluated. Few studies have been conducted to determine the effectiveness of residual herbicides sprayed onto cover crop residues compared to conventionally tilled systems. The overall objective of this trial was to determine if residual herbicides reach the soil surface providing benefits in a system utilizing high residue cover crop by measuring percentage of weed control, weed population counts, the length of weed control and weed biomass compared to conventionally tilled system. Field trials were conducted in Henry and Macon County in Alabama in 2019. Peanut treatments included; acetochlor 1,260, flumioxazin 107, diclosulam 26, *S*-metolachlor 1,700 g ha^{-1}, conventionally tilled non-treated check (NTC) and high residue NTC. Cotton treatments included; fluridone 168, acetochlor 1,260, fomesafen 280, fluometuron 1,680 g ha^{-1}, conventionally tilled NTC and high residue NTC. All treatments were applied with backpack sprayer the day of planting at 187 L ha^{-1}. Overall, total weed biomass in peanut plots with high residue cover and soi residual herbicides had significantly reduced weed biomass of 34%-89% compared to conventionally tilled NTC. Flumioxazin and diclosulam with high residue had the highest amount of weed biomass reductions of 89% and 82% respectively, compared to the conventionally tilled NTC in peanut. In cotton, all treatments including high residue NTC had significantly reduced weed biomass from 45-70% reductions compared to conventionally tilled NTC in Henry County. However, in Macon County, no herbicide treatment in combination with high residue or in conventionally tilled plots were significantly reduced from the conventionally tilled NTC in cotton. Overall, the combination of residual herbicides with a high cover crop residue provided more effective weed control overall compared to the conventionally tilled NTC meaning some residual herbicides are reaching the soil surface.

Impact of Four Winter Cover Crop Species and Termination Timing on Weed Suppression, Soil Moisture Dynamics, and Yield in Cotton. Spencer L. Samuelson*, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (473)

Cover cropping has witnessed limited adoption in South Texas, despite long growing seasons and continued accumulation of heat units after cash crop harvest. Some of the major limitations for cover crop adoption include a general lack of knowledge to facilitate cover crop selection, insufficient biomass production of covers prior to cash crop planting in spring, and perceived soil moisture depletion caused by cover crop growth, which may affect subsequent cash crop yield. The objectives of this study were to determine the effect of four winter cover crop species (triticale, oat, shield mustard, and Austrian winter pea) and termination timing (6-weeks, 4-weeks, and 2-weeks prior to cotton establishment) on cover crop biomass production, weed suppression, soil moisture dynamics, and cotton performance. The study was conducted from fall 2018 to fall 2019 at two locations: The Texas A&M University Research Farm, College Station, TX and the Stiles Foundation Farm, Thrall, TX. Cover crop termination timing had significant impact on biomass production, cotton stand establishment, and lint yield. Terminating cover crops 2-weeks prior to cash crop planting had a positive long-term effect on soil moisture. Triticale and oat provided substantial suppression of early summer annual weeds through live biomass, and provided additional weed suppression through residue cover after termination. The knowledge generated from this study will be helpful for making informed decisions on cover crop species selection and termination timing based on production goals.

Using Living Mulch in Reduced Tillage Sweet Corn. Alan W. Leslie*, Veronica Yurchak, Cerruti R. Hooks; University of Maryland, College Park, MD (474)

Sweet corn production systems typically incorporate tillage and residual herbicides to control weeds, however frequent tillage can reduce soil health and selection for herbicide resistant weed populations necessitates alternative strategies for weed control. Organic mulch from dead cover crop biomass provides a possible strategy for controlling weeds by suppressing annual weed germination. However, residue from killed cover crops decomposes over the growing season, and rarely can provide season-long suppression of weed growth. Alternatively, perennial cover crop species can work like a living mulch and actively compete with weeds the entire growing season, however competition between the living mulch and the crop must be minimized. In this experiment, we tested a biculture cover crop treatment, which incorporated alternating rows of an annual cover crop (rye *Secale cereale* (67 lbs/ac) or forage radish *Raphanus sativus* var. *longipinnatus* (10 lbs/ac)) with a perennial living mulch (red clover *Trifolium pratense*) living much to determine whether it could provide benefits of organic mulch and living mulch simultaneously. This treatment was compared against a standard mixture of rye (56 lbs/ac), crimson clover (*Trifolium incarnatum* 3 lbs/ac) and forage radish (3.5 lbs/ac) that was either planted with no tillage, or with conventional tillage. A residual herbicide treatment of atrazine, simazine, and s-metolachlor was applied as a split-plot with each cover crop/tillage treatment as the main plot to determine whether cover crops could have similar efficacy as standard herbicides. Initial results of the first year of this study show that the living mulch/organic mulch biculture treatments suppressed weeds as effectively as the standard tillage and herbicide treatment. Living mulch may be an effective alternative strategy for suppressing weeds in sweet corn, however limitations to this technique include increased difficulty in planting seeds with no tillage and the need for specialized equipment to apply the cover crop treatment at the correct row spacing.

Cover Crop-based Weed Management in Soybean Across mid-Atlantic, North-central, and South-central United States. Lovreet S. Shergill*[1], Mark VanGessel[2], Michael L. Flessner[3], Muthukumar V. Bagavathiannan[4], Kevin W. Bradley[5], John Lindquist[6], Jason A. Bond[7], Lauren M. Lazaro[8], Adam Davis[9], Jason K. Norsworthy[10], William S. Curran[11], Wesley Everman[12], George Frisvold[13], Nicholas Jordan[14], Larry Steckel[15], Steven B. Mirsky[16]; [1]USDA-ARS & University of Delaware, Beltsville, MD, [2]University of Delaware, Georgetown, DE, [3]Virginia Tech, Blacksburg, VA, [4]Texas A&M University, College Station, TX, [5]University of Missouri, Columbia, MO, [6]University of Nebraska-Lincoln, Lincoln, NE, [7]Mississippi State University, Stoneville, MS, [8]Louisiana State University AgCenter, Baton Rouge, LA, [9]University of Illinois, Urbana, IL, [10]University of Arkansas, Fayetteville, AR, [11]Penn State University, University Park, PA, [12]North Carolina State University, Raleigh, NC, [13]University of Arizona, Tucson, AZ, [14]University of Minnesota, Saint Paul, MN, [15]University of Tennessee, Jackson, TN, [16]USDA-ARS, Beltsville, MD (475)

The over-reliance on herbicides has limited the adoption of integrated weed management (IWM) practices and further intensified the ecological selection pressure contributing to herbicide-resistance evolution in weeds. Inclusion of cover crops (CCs) in crop rotations could diversify ecological selection pressure and aid in weed suppression. CCs are an important weed management tool because they occupy a niche otherwise available to weeds, thus depriving weeds through competition for resources. Once terminated, CC mulches suppress weeds physically by impeding emergence or attenuating environmental cues that break weed seed dormancy. Maximizing CC residue quantity (biomass) at termination is critical for physically suppressing weeds with CC residues. There is a vast amount of research that shows the potential impact of CC mulches on weed suppression; however, such work has primarily targeted individual weed responses at the local level. Farms are spatially variable and management practices for each farm differ from each other locally and regionally. Therefore, studies were conducted to understand the integration of CCs with other weed management tools such as herbicides across mid-Atlantic, North-central, and South-central United States. The results showed that late termination timing aids in greater accumulation of cereal rye biomass in both corn and soybean rotation. In the majority of cases, greater weed suppression was observed with later termination of cereal rye. However, to get season-long weed control integration of CC with a herbicide program was necessary. There were some regional differences in terms of biomass accumulation and weed suppression.

Evaluation of Post Emergence Applications of Mustard Seed Meal in Chile Pepper. Asmita Nagila*, Brian J. Schutte, Soum Sanogo, John Idowu; New Mexico state university, Las Cruces, NM (476)

Mustard seed meal (MSM) - meal by-products from Brassicaceae seed oil extraction - control some weeds and soil-borne pathogens when applied before crop emergence. MSM applications after crop emergence might be components of pest management programs, but these applications could be inappropriate because MSM-derived volatiles potentially injure the crop. The objectives of this research were 1) to identify post-emergence application technique that causes minimal MSM induced injury on chile pepper (Capsicum annum) under greenhouse conditions ,and 2) assess post-emergence applications of MSM for weed control and phytotoxicity on chile pepper under field conditions. For the greenhouse study, chile pepper was seeded in field soil and treatments were applied after 8wk of emergence. Treatments were factorial combinations of two rates (4400 kg MSM ha^{-1} [high] and 2200 kg MSM ha^{-1} [low]) and two application methods (soil surface and incorporation) and a nontreated control. For the field study, treatments were evaluated in four chile pepper fields across southern New Mexico. Field treatments were high and low rate of MSM treatment, each incorporated and compared against a non-treated control. Greenhouse study results indicated that post-emergence MSM reduced chile pepper photosynthetic rates within two days of application. These reductions lasted for high rate-surface treatment; but, for incorporated treatments, photosynthesis recovered to rates comparable to the control. At 14 d after application, non-treated controls and incorporated treatments were similar in chile plant height, biomass, and leaf area. A generalized linear mixed model conducted on field data indicated that MSM at high rate suppressed weeds but not reduce chile yield compared to control. Because these applications provide weed control without injury to the crop, post-emergence MSM can be a component of integrated pest management strategies for chile pepper production.

Manipulating Cropping Systems to Create a Better Harvest Weed Seed Control Target in Wild Oat (*Avena fatua*). Breanne D. Tidemann*[1], Larry Michielsen[1], Patty Reid[1], Jennifer Zuidhof[1], Elizabeth Sroka[1], Hiroshi Kubota[1], K. Neil Harker[2], Robert Gulden[3], Rebecca Dueck[4], Alick Mulenga[5], Cindy Gampe[5], Greg Semach[6]; [1]Agriculture and Agri-Food Canada, Lacombe, AB, Canada, [2]Agriculture and Agri-Food Canada (retired), Lacombe, AB, Canada, [3]University of Manitoba, Winnipeg, Canada, [4]University of Manitoba, Winnipeg, MB, Canada, [5]Agriculture and

Agri-Food Canada, Scott, SK, Canada, [6]Agriculture and Agri-Food Canada, Beaverlodge, AB, Canada (535)

Harvest weed seed control (HWSC) is a novel weed management technique with increasing adoption in Australia and increased global interest. One limitation to adoption of HWSC in western Canada is the low level of seed retention of wild oat and the resultant low ability to control wild oat with this technique. This study, conducted at 4 locations in the Prairies, examined whether including early maturing crops in a rotation allowed for a larger proportion of wild oat seeds to be targeted by HWSC. Treatments included 2 years of early, 'normal' and late maturing crop rotations in a factorial with swathed or straight cut harvest options. In the third year of the study all treatments were seeded to barley to allow for evaluation of wild oat populations, wild oat biomass and wild oat seed bank following three years of chaff collection. Wild oat population density was lowest following HWSC in early maturing crops, followed by 'normal' maturing crops and late maturing crops at two of the four locations. One location showed the lowest population density in the late maturing crops followed by the early and then the 'normal' maturity rotations while the final location showed no significant differences among treatments. Two of four locations had fewer wild oats using HWSC in combination with swathing, while the other locations had no significant differences between swathing and straight cutting. Location specific differences were also measured for wild oat biomass, and seed bank. Overall, this study shows cropping systems can be manipulated to create a better HWSC target in wild oat, however variability and unpredictability in seed shed is still problematic in terms of optimizing control levels.

The Weed Chipper: A Site-Specific Non-Chemical Weed Control Option for Conservation Cropping Systems. Andrew L. Guzzomi*[1], Michael J. Walsh[2]; [1]University of Western Australia, Crawley, Australia, [2]University of Sydney, Sydney, Australia (536)

Across the water-limited Australian cropping regions there is the frequent use of fallows for moisture storage in conservation crop production systems. In these commonly large cropping programs (~3000 ha) herbicides are relied on for effective and timely weed control. Whole field treatment frequently low weed densities (e.g. <1.0 plant 10 m^{-2}) is wasteful and exacerbates the herbicide resistance problems. Commercially available weed detection systems provide the opportunity for site-specific herbicide treatment for fallow weed control removing the need for whole field treatment when there are low weed densities. There is, however, concern over the continued reliance on herbicides for fallow weed control with growing interest in using weed detection systems for the application alternate weed control technologies, such as targeted tillage. This research was aimed at the development of a rapid response tyne enabling the site-specific fallow weed through the application of targeted tillage. Three small-scale prototypes were used for engineering and weed control efficacy testing across a range of species and growth stages. With confidence established in the design approach and a demonstrated 100% weed-control potential, a 6 m wide pre-commercial prototype, the “Weed Chipper” was built incorporating commercially available weed detection cameras for practical field-scale evaluation. This testing confirmed very high (90%) weed control efficacies and associated low-levels (1.8%) of soil disturbance where the weed density was <1.0 plant 10 m^{-2} in a commercial fallow. These data established the suitability of this mechanical approach to weed control for conservation cropping systems. The development of targeted tillage for fallow weed control represents the introduction of site-specific, non-chemical weed control for conservation cropping systems.

Nozzle Type and Arrangement Effect on Spray Coverage. Ashley N. McCormick*[1], Landon G. Smith[1], Troy W. Dillon[2], Thomas R. Butts[2], Brad M. Davis[2], Leah M. Collie[3]; [1]University of Arkansas System Division of Agriculture, Newport, AR, [2]University of Arkansas System Division of Agriculture, Lonoke, AR, [3]University of Arkansas System Division of Agriculture, Beebe, AR (537)

Arkansas row crop producers face many challenges throughout the growing season. One of which includes maintaining necessary spray coverage to achieve optimum levels of weed control. The objective of this research was to evaluate how nozzle arrangement (direction of emitted spray) and droplet size impacted spray coverage. Field experiments were conducted in a dry-seeded rice crop at the University of Arkansas at Pine Bluff Small Farm Outreach Center near Lonoke, Arkansas, and in an irrigated soybean crop at the Rohwer Research Station located near Rohwer, Arkansas. Rice and soybean were seeded in 19- and 97-cm row widths, respectively. Applications were made at 94 L ha^{-1} spray volume with a Bowman MudMaster (Bowman Manufacturing Co., Inc., Newport, AR 72112). Treatments consisted of four nozzle types [AIXR and TTI (TeeJet Technologies, Wheaton, IL 60187), 3D and ULD (Pentair Hypro, New Brighton, MN 55112)], three nozzle arrangements along the boom for the directional 3D and TTI nozzles (all forward, all backward, and alternating), and a nontreated control. This provided a total of nine treatments. Nozzle orifice sizes, spray pressures, and sprayer speeds were selected for each treatment to maintain the correct 94 L ha^{-1} spray volume while creating similar droplet size classifications between comparable nozzles. The AIXR and 3D nozzles produced a Coarse spray, while the ULD and TTI nozzles produced an Ultra Coarse spray. Data collection consisted of three water sensitive paper spray cards (Syngenta, Greensboro, NC 27419) per plot: a horizontal card at the top of canopy (top), a vertical card facing towards the direction of the sprayer (front), and a vertical card facing away from the direction of the sprayer (back). The spray cards were placed 15-cm from the soil surface on collection platforms near the center of each plot. Water sensitive cards were analyzed for spray coverage using DepositScan (USDA-ARS Application Technology Research Unit, Wooster, OH 44691). Coverage data were then subjected to ANOVA using SAS v9.4 (SAS Institute, Cary, NC 27513). No difference was observed in coverage between sites; therefore, sites were pooled. Initial results showed that greater spray coverage was achieved with the AIXR and 3D nozzles compared to the ULD and TTI nozzles. This is due to the AIXR and 3D nozzles emitting smaller droplet sizes and therefore, a greater number of droplets in the fixed spray volume were available to impact the spray card compared to the ULD and TTI nozzles. Additionally, the alternating nozzle arrangement for the directional 3D and TTI nozzles provided overall more uniform spray coverage on the top, front, and back of the collection surfaces than the other nozzle arrangements and was similar to that of the straight-down spray emission of the AIXR and ULD nozzles. Overall, this research highlights differences in spray coverage were achieved based on the nozzle selection and arrangement. Applicators may achieve better weed control through enhanced and more uniform spray coverage by implementing the alternating nozzle arrangement when using directional nozzles such as the 3D and TTI nozzles.

Continuing Evolution of Impact Mill Systems for Harvest Weed Seed Control. Michael J. Walsh*[1], John C. Broster[2]; [1]University of Sydney, Sydney, Australia, [2]Charles Sturt University, Wagga Wagga, Australia (538)

With majority of Australian growers (~60%) are now routinely using some form of harvest weed seed control (HWSC) there is demand for new and refined HWSC systems. Currently the most popular systems remain the low cost and simplistic chaff lining and chaff tramlining approaches that concentrate the weed seed bearing chaff into narrow rows during harvest. However, there is increasing interest in the use of the more sophisticated impact mill systems (e.g. iHSD and Seed Terminator) as this is the only approach that is fully compatible with conservation cropping as it allows the retention of all harvest residues. Current interest is being driven by research and development efforts over the last few years that have focussed on the refinement of current impact mill systems and the development of completely new ones. To determine the weed seed control efficacy of these new and improved systems a series of field trials were undertaken where the weed seed kill values were determined under controlled commercial harvest conditions. Additionally, the efficacy of chaff lining on annual ryegrass (*Lolium rigidum*) seed survival and emergence as impacted by sheep grazing was assessed. In a series of field trials during the 2017 wheat harvest in Western Australia the iHSD and Seed Terminator mills were compared while the new vertical and single mill versions of the iHSD were evaluated during the 2018 wheat harvest. Over-summer grazing resulted in a 38% reduction ($P<0.05$) in chaff biomass (equivalent of 3.2 t/ha) compared to the ungrazed chaff lines. Thus, even with a low yielding wheat crop (0.6 t ha^{-1}) concentration of chaff in lines enabled the consumption of a substantial amount of chaff biomass by grazing sheep. In April at the end of the trial only 15% of the annual ryegrass seed deposited at harvest remained in the grazed and ungrazed chaff lines. With similar levels of seed present in both treatments the then sheep grazing alone was not responsible for seed losses (85%). However, grazing did influence annual ryegrass emergence as the removal of chaff resulted in a 90% increase in seedling numbers in the grazed treatment. The annual ryegrass seed kill efficacy of the ST mill (99%) was slightly higher than that of iHSD mill (95%) when these systems were compared in almost identical harvesters. A Vertical iHSD mill system has been developed with improved functionality of access to the rear of the harvester and a collection system for large potentially mill damaging objects. Similarly, a single mill iHSD system has been developed for use on lower powered harvesters. Commercial field testing of the vertical and single mill iHSD systems determined that high annual ryegrass seed kill levels (94 to 96%) were achieved by these systems respectively across a wide range of chaff throughputs during wheat crop harvest. Grower interest in the use of impact mill systems has resulted in the recent introduction of two new impact mill systems. In 2018 Redekop® introduced the “Seed Control Unit”, that is incorporated with their MAV straw chopper system. In 2020 Tecfarm a Western Australian company introduced the “WeedHog” which is focused on the principles of reduced energy requirement and low cost. The adoption of impact mill systems is expected to grow rapidly over the next few years as the functionality of impact mill systems improves and they continue to decrease in price.

Weed-Sensing Technology Reworks Fallow Management of Rush Skeletonweed (*Chondrilla juncea* L.). Jacob W. Fischer*, Mark Thorne, Drew J. Lyon; Washington State University, Pullman, WA (539)

Rush skeletonweed is an aggressive perennial weed that establishes itself on land enrolled in the conservation reserve program, and persists into cropland following expiration of the contract. It depletes critical soil moisture required for yield potential of winter wheat. Fallow weed control is dominated by glyphosate and tillage because of their comparatively low cost. Research was conducted at two sites in eastern Washington, Lacrosse and Hay, to evaluate the effectiveness of a weed-sensing sprayer compared to broadcast applications of four herbicides (aminopyralid, chlorsulfuron/metsulfuron, clopyralid, and glyphosate) for control of rush skeletonweed. The study used a split-plot experimental design with herbicide and application type as main and subplot factors, respectively. Herbicides were applied in the fall at either broadcast or spot-spraying rates depending on sprayer type. Aminopyralid (1.1 plants m^{-2}), glyphosate (1.4 plants m^{-2}), clopyralid (1.7 plants m^{-2}), and chlorsulfuron/metsulfuron (1.8 plants m^{-2}) reduced rush skeltonweed density in May compared to the nontreated check (2.6 plants m^{-2}). No treatment differences were observed after May 2019. There was no significant interaction between herbicide and application system. The weed-sensing sprayer reduced spray volume on average by 52% ($p<0.001$) at Lacrosse and 20% ($p=0.01$) at Hay. Spray reduction is dependent on weed density. At Lacrosse, the weed-sensing sprayer reduced costs for all herbicide treatments except aminopyralid, with savings up to 6.8 US dollars ha^{-1}. At Hay, using the weed-sensing sprayer resulted in economic loss for all products. The weed-sensing sprayer is a viable fallow weed control tool when weed densities are low or patchy.

Advances in Precision Weed Management 2020. Vijay Singh*[1], Daniel Martin[2], Mohamed Latheef[2], Bishwa B. Sapkota[3], Muthukumar V. Bagavathiannan[3]; [1]Virginia Tech, Painter, VA, [2]United States Department of Agriculture, College Station, TX, [3]Texas A&M university, College Station, TX (540)

Unmanned Aerial System technologies are widely used for mapping and classification of weeds these days. The high-resolution imagery data can provide information for optimizing management decisions and precise weed control. Along with real-time image data, UAS have the potential to be used for herbicide spray applications. Herbicides are relied upon as an important tool for weed management in row-cropping systems. Studies have been conducted in 2018 and 2019 for a thorough assessment of dominant weed species, weed growth stage, size of crops and their impact on UAS-based herbicide efficacy. Herbicide (glufosinate) was applied as early- and late-POST treatment. Results have indicated that UAS-based herbicide applications provided 100% weed control even at a low spray volume of 18.7 L ha^{-1} (2 GPA) compared to 75% control with backpack sprayer at 140 L ha^{-1} when applied at late-POST stage. Early-POST applications have indicated similar efficacy when applied with UAS at 18.7 and 37.4 L ha^{-1}, and with backpack sprayer at 140 L ha^{-1}. However, nozzle selection played key role in improving the herbicide efficacy of UAS-based spray applications. UAS-based imagery and spray applications can address primary agricultural challenges but more research is required on understanding and optimizing the operational conditions.

Effects of Cover Crops on Nutrient Dynamics and Weed Communities. Karla L. Gage*[1], Rachel Cook[2], Randy McElroy[3], Gurbir Singh[1], Jon Schoonover[1], Karl Williard[1]; [1]Southern Illinois University Carbondale, Carbondale, IL, [2]North Carolina State University, Raleigh, NC, [3]Bayer Crop Science, Farina, IL (541)

Cover crops (CC) may have the ability to enhance agroecosystem resiliency to environmental stochasticity through the addition of soil organic matter and nitrogen, reduction of erosion and nutrient loss, and the increase of soil water infiltration. Cover crops may also offer some degree of weed suppression in addition to these benefits to soils, and the environmental changes associated with cover crops may cause a shift in the assemblage of weed species over time and impact crop yield. A long-term study was established in the fall of 2014 in Carbondale, Illinois to study the effects of CC and no CC rotations (Corn (*Zea mays* L.)-cereal rye (*Secale cereale* L.)-soybean (*Glycine max* L. Merr.)-hairy vetch (*Vicia villosa* R.) [CcrShv], corn-cereal rye-soybean-oat+radish (*Avena sativa* L.+*Raphanus sativus* L.) [CcrSor], and corn-noCC-soybean-noCC [CncSnc]) and two tillage systems, no-tillage and conventional tillage. The effects on crops and cover crops were measured through variables such as C:N ratio, nitrogen uptake, and yield. Weed seedbanks were examined for changes over time, as well as rotational and tillage effects. Over a four-year period, it was determined that corn yield was greater when planted following a hairy vetch cover crop, rather than no cover crop or oats+radish. Cereal rye sequestered more nitrogen than weeds alone in the no CC treatment. Soybean yields, however, were greater when planted following no CC in no-tillage or conventional tillage. Across four seedbank growouts from study initiation in fall 2014 to spring 2016, the most common species in order of greatest to least occurrence were: *Lamium amplexicaule* L., *Cerastium fontanum* subsp. *vulgare*, *Veronica peregrina* L., *Stellaria media* (L.) Vill., *Draba brachycarpa* Nutt., *Mollugo verticillata* L., *Amaranthus tuberculatus* (Moq.) Sauer, *Cardamine parviflora* L., *Myosurus minimus* L., *Poa annua* L., *Draba verna* L., *Packera glabella* (Poir.) C. Jeffrey, *Oxalis stricta* L., *Capsella bursa-pastoris* (L.) Medik., *Ranunculus abortivus* L., *Sonchus oleraceus* L., and *Conyza canadensis* (L.) Cronquist. While the species assemblages were different over time, there was no discernible effect of rotation after only two years of study. However, there was an impact of tillage on the species assemblage. Seedbank growouts are ongoing for this study to monitor for shifts over time and will be analyzed for relationships between species functional traits and species response to management.

Cover Crop Planting Date and Weed Emergence in Almond Orchards. Steven C. Haring*[1], Brad Hanson[2]; [1]University of California, Davis, Davis, CA, [2]University of California, Davis, Winters, CA (542)

Among other ecosystem services, weed management is increasingly recognized as a benefit of cover crops in many cropping systems. Winter annual cover crops may be integrated into California orchard systems so that they emerge with winter rains and compete with winter weeds. Based on our previous studies, we think that a timely cover crop planting, before winter weed emergence, can facilitate a competitive cover crop. We planted two five-species cover crop mixes in a nonbearing almond orchard near Winters, CA in a randomized complete block design with five replicates. The cover crops were direct-seeded into the alleys between tree rows, such that each plot was five trees long and two alleys wide, about 26 m by 12 m. Each cover crop mix was planted at an early planting date, in the fall after most growers would complete almond harvest. Separate late planting treatments were planted over the winter after winter orchard sanitation would typically be complete. These early and late plantings occurred in October 2018 and January 2019 and were repeated in October 2019 and February 2020. All treatments received disk tillage before early planting while the late planting treatments and nontreated controls received an additional burndown herbicide application ahead of the late planting date but no additional tillage. We monitored orchard vegetation throughout the cover crop growing season with weekly 10-m long point-intercept transects and then harvested cover crop biomass at the time of termination, in April 2019. In both years of the study, the first significant winter rains occurred in late November, approximately five to six weeks after the early cover crop planting. By this time, more small-statured broadleaf weeds had emerged than cover crops. Cover crops and weeds both emerged relatively quickly after the late planting. By the end of the growing season, the two early planting treatments produced more cover crop and weed biomass compared to the late planting treatments. These results support the hypothesis that a timely cover crop planting results in more cover crop biomass but suggest that an early planted cover crop is not necessarily more competitive nor weed-suppressive. Winter weeds appear more likely to emerge before winter rains compared to the cover crop species used here, possibly limiting the benefits of an early planting date. The burndown herbicide application ahead of the late cover crop planting represented an increased level of management intensity compared to the early planting treatments. The second year of this experiment will be completed in April 2020

Seasonal Variability in Pre-harvest Seed-dispersal in *Hordeum glaucum* (Smooth Barley) and *Bromus diandrus* (Ripgut Brome) - Implications for Harvest Weed Seed Control. Daniel Petersen, Gurjeet S. Gill*; University of Adelaide, Adelaide, Australia (543)

Harvest weed seed control (HWSC) tactics are used by grain growers in Australia to minimize seed bank replenishment by exploiting the high levels of seed retention until crop harvest in weed species, such as rigid ryegrass (*Lolium rigidum*). Australian grain growers urgently need information that substantiates the vulnerability to HWSC in other important weeds, such as smooth barley and ripgut brome. In a field study in consecutive seasons from 2016 to 2018, temporal patterns of seed dispersal of these two weed species were determined by monitoring capture trays at weekly intervals during crop ripening. Senescence and seed dispersal of smooth barley and ripgut brome started 42-49 days and 21-28 days earlier than wheat maturity, respectively. Smooth barley appears to have low susceptibility to HWSC strategies because most seed (91-93%) dispersed before harvest maturity of wheat in 2016 and 2017. Severely dry conditions in 2018 affected plant development and reduced pre-harvest dispersal in smooth barley to 40%, but many spikes (30% ± 9%) were present below the harvest height (150 mm) at crop maturity and were likely to escape HWSC. Ripgut brome exhibited large variation in seed dispersal between the seasons. There was low seed dispersal in 2018 (9%), a moderate level in 2016 (30%) and high seed dispersal in 2017 (80%). Capture of ripgut brome seed by the HWSC tactics would also be reduced by extensive panicle lodging in 2016 (80% ± 2%) and 2017 (51% ± 10%). The high levels of seed retention in ripgut brome in some seasons suggests that threshing systems on commercial harvesters need to be able to separate its seeds from crop grain to alleviate the economic risk of exceeding grain impurity thresholds. This study has demonstrated that HWSC is likely to have moderate and variable effectiveness for these two species, but patterns of pre-harvest seed dispersal are difficult to predict because of their responsiveness to seasonal variation.

Evaluation of Rate and Timing of Herbicide Application During the Establishment of a Living White Clover (*Trifolium repens*) Mulch for Field Corn Production. Nicholas T. Basinger*, Nicholas S. Hill; University of Georgia, Athens, GA (544)

With increasing focus on controlling herbicide resistant weeds many producers have turned to annual cover crops to aid in controlling these resistant weeds. Recent studies have suggested that perennial cover crops such as white clover (*Trifolium repens* L.) may have weed control benefits in corn production systems while also providing additional N and stabilizing soil. However, white clover is slow to establish in the fall and winter and winter weeds such as wild radish (*Raphanus raphanistrum* L.), cutleaf evening primrose (*Oenothera laciniata* Hill), and common vetch (*Vicia sativa* L.) often compete with the establishing clover, leaving bare ground areas within the cover crop. Field studies were conducted in the fall and winter of 2018 at the J. Phil Campbell Research and Education Center in Watkinsville, GA and the Southeast Georgia Research and Education Center in Midville, GA. White clover was seeded at each site. Herbicides were applied either as a PRE (pendimethalin; 672.5 g ai ha^{-1}) or POST when clover reached 2-3 trifoliate. POST applications of imazethapyr (70 g ai ha^{-1}), bentazon (840.6 g ai ha^{-1}) flumetsulam (5g ai ha^{-1}; 10 g ai ha^{-1}), or combinations of 2,4-D (105 g ai ha^{-1}), 2,4-DB (1492 g ai ha^{-1}), and flumetsulam (5g ai ha^{-1}). Six weeks after the initial application, a sequential application of bentazon (840.6 g ai ha^{-1}), flumetsulam alone (5 g ai ha^{-1}) and combinations of combinations of 2,4-D (105 g ai ha^{-1}), 2,4-DB (1492 g ai ha^{-1}), and flumetsulam (5 g ai ha^{-1}) were applied over designated plots. Visual ratings for clover injury, and weed control by species were collected at (1, 2, 4, 6, 7, 8, and 10 weeks after initial application). Clover biomass and weed biomass by species was collected prior to field corn planting in the spring. Visual ratings at Midville, GA at 6 weeks after application showed, 94%, 87,% and 83% control of cutleaf evening primrose, and 90%, 88%, and 66% control of wild radish for flumetsulam (10 g ai ha^{-1}), 2,4-D + 2,4-DB + flumetsulam (5 g ai ha^{-1}), and 2,4-D + 2,4-DB respectively. At 10 weeks after application, a single application of flumetsulam (10 g ai ha^{-1}) resulted in 94% control of both cutleaf evening primrose and wild radish. Sequential applications of 2,4-D + 2,4-DB resulted in 97% and 75% control of cutleaf evening primrose and wild radish, respectively at 10 weeks after application. 2,4-D + 2,4-DB + flumetsulam (5 g ai ha^{-1}) resulted in 93 and 97% control of cutleaf evening primrose and wild radish, respectively. All POST applications resulted in greater weed control than the pendimethalin treatment, and clover biomass was unaffected by any herbicide treatment at both sites. At the Midville, GA location single applications of flumetsulam (10 g ai ha^{-1}) or a tank mix of 2,4-D, 2,4-DB and flumetsulam (5 g ai ha^{-1}) and sequential applications of 2,4-D + 2,4-DB were most effective in reducing cutleaf evening primrose and wild radish biomass. At the Watkinsville, GA location no POST option effectively controlled common vetch when compared to the control. Results indicate that all herbicides in the study were safe to use during the establishment of white clover living mulch at both locations and a single application of flumetsulam (10 g ai ha^{-1}) provided the most overall control of cutleaf evening primrose, wild radish, and common vetch.

Soybean Response to Sublethal Dosages of Dicamba Particle Drift Vs. Vapor. Frances B. Browne[1], Steve Li*[1], Katilyn J. Price[1], Ryan D. Langemeier[1], Greg R. Kruger[2]; [1]Auburn University, Auburn, AL, [2]University of Nebraska-Lincoln, North Platte, NE (545)

Increased usage of dicamba following commercialization of crops with engineered resistance has led to unprecedented numbers of drift complaints across the US. Particle drift and volatilization of dicamba have been targeted as primary sources of off-target movement. In order to compare soybean response at early bloom to dicamba particle drift and vapor, field studies were conducted in Macon County, AL and Lincoln County, NE. Broadcast applications of dicamba at 0.03, 0.14, 0.70, 3.51, 14.04, 35.07, and 140.28 g ae ha^{-1} were used to simulate particle drift in 2017, 2018, and 2019. Vapor drift was simulated through plastic tunnels placed over two rows of soybean to concentrate vapor emitted from soil pans treated with dicamba at 0.56, 5.59, 56.42, 559.17, 5591.75, and 11183.51 g ae ha^{-1} in 2018 and 2019. Visual injury was recorded 7, 14, 21, and 28 days after treatment (DAT) in addition to yield at harvest. Dicamba particle drift was more injurious to soybeans as compared to vapor. Visual injury resulted from particle drift ranged from 3% to 100% across site-years. However, soybean visual injury resulted from vapor exposure did not exceed 55% regardless of dosage. The lowest rate of dicamba particle drift to result in soybean yield loss across all site-years was 1.4 g ae ha^{-1}. Alternatively, vapor emitted from the highest rate of dicamba tested at 11183.51 g ae ha^{-1} did not result in soybean loss yield relative to the nontreated control. Nonlinear regression suggests yield was highly responsive to dicamba particle drift. However, no significant relationship between vapor dosage and yield was observed. Similarly, soybean yield was correlated to visual injury resulted from particle drift and not vapor. These data suggest visual injury is a poor indicator of yield loss. Soybean response to dicamba particle drift is not comparable to vapor.

Driver Weeds and the Balance of Control Option Space. Anita Kuepper*[1], Frank Rothweiler[2], Tracy Klingaman[2], Hubert Menne[3], Philipp Welter[4], Catherine de Vulder[4]; [1]Bayer Cropscience, Frankfurt, Germany, [2]Bayer AG, St. Louis, MO, [3]Bayer AG Crop Science, Frankfurt, Germany, [4]Bayer AG, Monheim, Germany (546)

For the past decades agricultural weed control has largely been based on the use of herbicides due to their ease-of-use, cost-effectiveness and efficiency. It allowed for many benefits like decreased soil erosion and carbon emissions but also brought upon challenges like the emergence of resistant weed populations. The selection pressure of this particular weed control system influences which weeds stay common weeds and which weeds turn into resistant driver weeds. The presentation will provide a global overview of the current driver weeds in the most prevalent crop rotations of major agricultural producing countries. How problematic a particular driver weed turns out to be not only depends on the number of sites of action it has evolved resistance to but also on the number of sites of action that still remain available to the farmer for its control. This chemical control option space has steadily been decreasing over the years and, for certain driver weeds, likely cannot be outpaced by new herbicide innovation in the long run. It makes the preservation of the remaining chemical and non-chemical control options by practicing integrated weed management ever more important.

Annual Bluegrass Management in Cool-Season Grasses Grown for Seed in Oregon: A Meta-Analysis of Multiple Years of Internal Data. Seth Bernard E. Abugho*, Caio A. Brunharo, Andrew G. Hulting; Oregon State University, Corvallis, OR (547)

Tall fescue (*Festuca arundinacea* Schreb.) and perennial ryegrass (*Lolium perenne* L.) seed production requires effective weed management to manage problematic grasses. In Oregon, annual bluegrass (*Poa annua* L.) is considered a major weed in tall fescue and perennial ryegrass, and much is known about the management practices of annual bluegrass in seed grass fields. A meta-analysis of 73 previously conducted field studies at Oregon State University from 2008 to 2018 was conducted with the objectives to (1) quantify the effect of herbicide programs on the injury of annual bluegrass and seed yield of grass crops; (2) identify the herbicide sites of action that are used at each time of application; and (3) to identify application timings of herbicides that favor annual bluegrass control and seed yield of grass crops. Overall, annual bluegrass injury increased by 10% between 21 and 60 days after herbicide application (DAA) in September for both grass crops. Herbicide applied in the month of September and October provided >70% annual bluegrass control at 21 DAA. Regardless of application timing, WSSA herbicide groups 2, 9, 15, and 29 provided >75% annual bluegrass control in both crops. Annual bluegrass control evaluated at 21 DAA and 60 DAA increased by 10% to 20% for herbicides applied as part of a sequential herbicide weed management program compared to sole applications. Grass seed yields ranged from 1090 to 1170 lbs acre^{-1} and 900 to 1200 lbs acre^{-1} in perennial ryegrass and tall fescue, respectively. No yield reduction was observed regardless of herbicide applied alone or in combination with other sites of action. Future research should include weed seedling count to estimate the weed density infestation in relation to seed yield. Our results highlight the optimum window of herbicide application and effective sites of action that can be used as useful tools in the integrated weed management of annual bluegrass in perennial grass seed production systems.

WSSA SECTION 14: TRAVEL ENRICHMENT EXPERIENCE

Tackling Toadflax in Montana. Jessica E. Quinn*; University of Guelph, Ridgetown, ON, Canada (548)

As a recipient of the WSSA Graduate Student Travel Enrichment Experience award, I had the opportunity to learn first-hand about biological weed control. In August 2019 I travelled to Bozeman, Montana with a fellow graduate student, Nicole Langdon, to visit Dr. Sharlene Sing and Dr. Sarah Ward for three days. Their research focuses on the management of invasive weeds on federal and state-owned forest and rangeland, using biological control methods. Having a background primarily in chemical weed control, Nicole and I were intrigued with biological control methods. Over the three days, Dr. Sing and Dr. Ward taught us about the years of research, extensive regulatory measures and strategic implementation of biological control agents. Our learning experience focused on the challenges associated with the control of invasive Dalmatian toadflax (*Linaria dalmatica (L.) Mill.)*, yellow toadflax (*Linaria vulgaris Mill.)* and the more recently discovered hybrids (yellow x Dalmatian). Not only were Nicole and I continuously learning during this experience, but we were able to experience the beauty of the Montana Rockies and visit Yellowstone National Park. This experience was one of the highlights of my MSc. degree and I am very grateful to have been provided with this unique opportunity. Many thanks to Dr.'s

Sharlene Sing and Sarah Ward for making our trip so wonderful, and to the WSSA for providing students with such a unique learning experience.

From Inception to Market: Learning the Herbicide Registration Cycle with Syngenta. John A. Schramski*[1], Carroll Moseley[2], Janis E. McFarland[3]; [1]Michigan State University, East Lansing, MI, [2]Syngenta, High Point, NC, [3]Affiliation Not Specified, Chapel Hill, NC (549)

As graduate students, we learn about, apply, and evaluate numerous herbicides and mixtures. However, most of our interactions with the companies that work so hard to bring these products to market are limited to our local technical representatives and those that attend weed science conferences. We seldom get to understand the full process and meet the people associated with obtaining and maintaining a herbicide label. As one of the WSSA Graduate Student Travel Enrichment Experience recipients, I was able to meet employees with industry jobs I was previously unaware existed. In September 2019, I traveled to Greensboro, NC for a week to visit Syngenta's North American headquarters while being hosted by Dr. Carroll Moseley. During this week, I met with Syngenta employees from every aspect of the herbicide registration cycle. I learned about the wealth of data generated prior to submission of a label to the EPA, and how Syngenta goes above and behind to promote stewardship of agricultural products. I also met with employees who work with products after they are labeled and learned more about sales/marketing, agronomic support, and product reregistration. In addition, I was able to get a tour of agriculture in North Carolina and visit Syngenta's Research Triangle Park Innovation Center. The opportunity to visit Syngenta for a week has provided me a deeper understanding and appreciation for what it takes to discover, register, and maintain pesticide product registrations. I am forever grateful for those that took the time to educate me and I encourage all graduate students to apply for these opportunities.

A Week in the West - My 2019 Travel Enrichment Experience with Syngenta. Nicholas R. Steppig*; Purdue University, Lafayette, IN (550)

As a recipient of the 2019 WSSA Travel Enrichment Experience, I had the opportunity to travel to Meridian, Idaho, to spend four days with Dr. Marty Schraer. Traveling with Dr. Schraer, who serves as a Research and Development Scientist with Syngenta, provided me with a firsthand look at day-to-day life for someone serving in a role that I hope to take on in the future. During my trip, the diversity of Idaho agriculture was immediately apparent, as I encountered wheat, potato, sugarbeet, onion, hops, corn, soybean, and several crops grown for seed production. Dr. Schraer demonstrated that the life of a successful industry R&D scientist requires not just an expertise in weed science, but a well-rounded understanding of entomology, pathology, and nematology as well. In addition to a traditional understanding of the sciences related to agriculture production, my time spent in Idaho also reinforced the importance of soft skills that are required to be effective in this role. Dr. Schraer's strong interpersonal skills, his ability to effectively manage both time and data, as well as the capability to solve problems that arise on an everyday basis, are certainly reasons he has had a productive career for Syngenta, and traits I hope to be able to emulate in the future. I truly appreciate the hospitality I received from Marty during my trip, as well as the funding from the WSSA in support of the Travel Enrichment Experience, and strongly encourage other graduate students to apply for this unique opportunity in the future.

Agriculture Beyond Borders: Tifton to Saskatoon. Kayla M. Eason*; University of Georgia, Tifton, GA (551)

In the summer of 2019, thanks to the WSSA Graduate Student Travel Enrichment Experience award, I was able to travel nearly 2,200 miles into the heart of Canadian agriculture. I was fortunate enough to visit with Dr. Steve Shirtliffe and Dr. Eric Johnson at the University of Saskatchewan in Saskatoon, Saskatchewan. For this experience, I wanted to learn about the agricultural industry in Canada and see the multitude of crops not grown in my region of South Georgia. During my visit at USASK, I spent time with a wide variety of people in a wide variety of disciplines. From weed management in canola to lentil breeding, my time in Saskatoon was consistently filled with learning about the diverse cropping systems in the "Land of the Living Skies". From pulse crops to canary seed, the management techniques and overall agronomic practices were incredible to learn and see implemented in the field. I am very thankful for this incredible experience and the amazing hospitality of Dr. Shirtliffe's and Dr. Johnson's students and staff.

Specialty Weeds at Commodity Scale; California's Central Valley. Samuel A. Palmer*; University of New Hampshire, Epsom, NH (552)

Abstract not available

The Intersection of Weed Science and Politics: What I Learned During My Fellowship in DC. Haleigh Summers*[1], John A. Schramski[2], Lee Van Wychen[3]; [1]Weed Science Society of America, Ames, IA, [2]Michigan State University, East Lansing, MI, [3]Weed Science Society of America, Alexandria, VA (553)

Weed scientists strive to educate stakeholders and the general public about the impact of weeds in managed and natural ecosystems. A key stakeholder group that can have a large influence on the allocation and regulation of resources to research and manage weeds are policy makers and elected government officials. The goal of the Weed Science Society of America (WSSA) Science Policy Committee is to educate and inform policy makers of potential impacts of their decisions on weed science and agriculture as a whole. This important sector of the WSSA is often overlooked by young weed scientists. The Weed Science Policy Fellowship (WSPF) provides a unique opportunity for graduate students to assist the WSSA Executive Director of Science Policy, Dr. Lee Van Wychen, while gaining experience with weed science policy issues. This past year, John Schramski and Haleigh Summers were able to participate in numerous weed science policy activities both remotely and in Washington, DC. As WSPFs, they represented the WSSA by writing comments to the EPA on important rules and regulations such as the Revised Definition of "Waters of the United States", Glyphosate Proposed Interim Registration Review Decision, Potential Synergistic Effects of Pesticides during the Registration Process, and Revision of the Application Exclusion Zone Requirements: Pesticides. On trips to Washington, DC, they represented weed science at meetings such as 5-year review of the USDA-ARS National Program 304 - Crop Protection and Quarantine Program, the IR-4 Annual Priority-Setting Workshop, and the Herbicide Resistance Education Committee planning meeting. They were also able to sit in on a House Agriculture Committee meeting and discuss important weed science topics with the offices of members of Congress, the USDA, EPA, as well as various lobbying groups. During this fellowship, John and Haleigh learned about the importance of advocating for weed science and funding opportunities to both members of congress and federal agencies and. The WSPF provides a unique opportunity to experience a broad array of weed science policy issues and better understand intricacies of science policymaking.

SYMPOSIUM 1: 2020 Vision for Hawaiian Invasive Plant Management

Introduction to Symposium. David R. Clements*[1], Curtis Daehler[2]; [1]Trinity Western University, Langley, BC, Canada, [2]University of Hawaii at Manoa, Honolulu, HI (412)

Abstract not available

Invasive Plant Establishment and Spread in the Hawaiian Islands: History, Current Trends, and Strategies for Prevention. Curtis Daehler*, Kelsey Brock; University of Hawaii at Manoa, Honolulu, HI (413)

Over the past century, the number of documented naturalized plants in the Hawaiian Islands has increased roughly linearly at a rate of around 11 new species per year. Not all naturalized plants will become important economic or environmental weeds, however recently documented naturalized species do include some serious weeds, such as Chromolaena odorata. Over the last 20 years, two approaches have been utilized to help reduce the establishment of new weeds in the Hawaiian Islands. The Hawaii-Pacific Weed Risk Assessment (HPWRA) has been used to assess risk for over 2000 non-native plants, including new arrivals and proposed introductions. HPWRA identifies high risk species, however, there is no available legal means in Hawaii to prevent entry or prevent planting of high risk species identified by HPWRA; thus, efforts have focused on plant industry and consumer education to reduce importation and planting of high risk plants. The second approach has been to establish Island Invasive Species Committees (ISCs) on each of the main islands. These partnerships of state, federal, and private agencies have worked to identify incipient invasions and implement control plans. To date, the ISCs have likely slowed the establishment or spread of various target species (e.g. *Miconia calvescens* on Kaua'i and O'ahu). Some weedy species have been successfully eradicated from islands by ISCs, such as Senecio madagascariensis (fireweed) from Kaua'i; however, eradications have been difficult to document, partly because documentation requires time as well as resources. Among new plant naturalizations reported in the past 20 years that have been assessed by the HPWRA, 105 species (55%) have HPWRA ratings of high weed risk while among species first reported as naturalized 50-100 years ago 88% have HPWRA ratings of high weed risk. One possible interpretation is that increased awareness in recent decades has led to a somewhat lower percentage of naturalizations that have high weed risk; on the other hand, with 55% of recent naturalizations rated as high risk, this leads to a predicted 6 new economic or ecological weeds being naturalized per year, indicating a need for more effective strategies to prevent establishment of new serious weeds in Hawaii.

The Risk and Resources for Mitigating an Incipient Miconia Invasion. David Lewis*[1], James Leary[2], Kimberly Burnett[3], Chris Wada[3], Brooke Mahnken[4]; [1]University of Hawaii at Manoa-Department of Natural Resources and Environmental Management, Honolulu, HI, [2]University of

Florida, Gainesville, FL, [3]University of Hawaii at Manoa- University of Hawaii Office of Economic Research, Honolulu, HI, [4]University of Hawaii at Manoa- Maui Invasive Species Committee, Makawao, HI (414)

Miconia (*Miconia calvescens* DC) was introduced to the East Maui Watershed (EMW) almost a half century ago. Fast forward two decades later with the realization of miconia becoming a major ecological problem leading to the epochal formation of the Melastome Action Committee; a first-of-its-kind grassroots, multi-agency coordination effort to eradicate an invasive species in Hawaii. Fast forward another 25 years with over 1.5 M miconia plants eliminated and likely over a million more continuing to occupy and expand into new areas across 30% of the watershed. Despite the valiant efforts by many hardened individuals, it is surmised that the miconia invasion cannot be eradicated nor comprehensively contained. Funding has been declining over the last decade and at this juncture, a decision to terminate all future management might seem logical. However, this would come with great irreparable damage to the EMW which continues to serve as critical habitat to over 100 endemic threatened and endangered species and produces billions of gallons of clean, potable water. Here, we propose an alternative to downscale from comprehensive management to protection of finite assets that can be intensively managed on a small scale. We've developed a mechanistic spread model that displays random dispersal among the progeny of an incipient population over a 20-yr time horizon that is based on our empirical interpretation of a leptokurtic dispersal kernel with rare long distance deposits. We further created different scenarios of a “last stand” protecting an asset area within range of an encroaching incipient population. Here we show how net present values and benefit-cost ratios are used to determine when management should retreat to within the boundary of the asset area versus a more forward pre-emption eliminating miconia outside of the boundary. Regardless, with any option at this late stage, the end result is fait accomplii; the agony of defeat by attrition.

Synergies Between Nonnative Ungulate and Plant Invasions in Hawai'i - Can the Tide be Turned? Creighton M. Litton*[1], Rebecca J. Cole[2], Jed P. Sparks[3], Christian P. Giardina[4], Amanda Knauf[1]; [1]University of Hawaii at Manoa, Honolulu, HI, [2]Osa Conservation, Puerto Jiménez, Costa Rica, [3]Cornell University, Ithaca, NY, [4]Institute of Pacific Islands Forestry, USDA Forest Service, Hilo, HI (415)

Nonnative ungulates negatively impact native biodiversity throughout the Pacific Island region. As a result, land managers commonly fence and remove nonnative ungulates to conserve native biodiversity. However, ungulate removal is labor and cost intensive, requires continual maintenance, and long-term outcomes are not well quantified. In particular, little is known about the extent of recovery for native vs. nonnative plants or the time frame under which vegetation responds following ungulate removal. In addition, little is known about how ungulate removal impacts underlying soil processes, despite the fact that these impacts likely persist for decades and have a strong influence on vegetation response via aboveground-belowground feedbacks and linkages. We examined chronosequences of fenced conservation units on Hawaii Island in montane wet forest and three montane dry ecosystems to examine how native and nonnative vegetation and underlying soil physical, chemical and biological properties respond to nonnative ungulate removal over time. Plant community responses to ungulate removal varied somewhat across ecosystem types. Common native plants responded positively to ungulate removal in two of four ecosystem types. In turn, native species of conservation interest recovered with ungulate removal in all four ecosystem types. Finally, nonnative plants responded positively to ungulate removal in three of four ecosystem types. Ungulate removal had a large impact on soil physical, chemical and biological properties, altering basic soil parameters that feedback to aboveground vegetation. In particular, we found evidence that ungulate removal increases the cycling and availability of soil nutrients in all three ecosystem types examined. Prior studies have indicated that nonnative plants are better able to take advantage of increased resource availability than native plants. As such, we conducted a greenhouse experiment to examine how soil nutrient availability impacts native vs. nonnative plant competition. We found that both nonnative species tested were competitively superior under conditions of high resource supply, while all but one native species tested were more competitive under conditions of reduced resource availability. Collectively, this research highlights that nonnative ungulate removal alone is insufficient to attain long-term conservation goals to promote native biodiversity, as least partially as a result of changes in underlying soil processes. Management strategies that reduce resource availability following ungulate removal should be tested as a means of promoting native plants following nonnative ungulate removal.

Challenges for Restoration of Invaded Hawaiian Landscapes: Why We Need the Hybrid Ecosystem Concept. Rebecca Ostertag*[1], Nicole DiManno[1], Susan Cordell[2], Amanda Uowolo[2]; [1]University of Hawaii at Hilo, Hilo, HI, [2]Institute of Pacific Islands Forestry, USDA Forest Service, Hilo, HI (416)

The application of the hybrid ecosystem concept in restoration allows for reconfiguration of landscapes that have been altered from their historical species composition to a new state. This hybrid restoration approach may be necessary due to the increasing prevalence of global factors including climate change, urbanization, and invasion. We examined whether hybrid ecosystem restoration can be a viable strategy for cultivating forest growth, facilitating native biodiversity and invasion resistance in an on-going restoration project in a lowland Hawaiian wet forest. Hybrid ecosystems were created after removal of all invasive species and subsequent planting of four different combinations of native and exotic (non-native, non-invasive) plant species. After 6 yrs of experimentation, survival of outplants averaged 60-80% and percent canopy cover has rebounded to over 80%. There is a strong correlation between canopy closure and the person hours required for weeding. The development of canopy facilitated invasion resistance: 1) a drop in invasive plant cover by at least 2/3 relative to initial starting conditions (invaded forest) and 2) a ~35% decrease in weeding effort from the first weeding interval. Furthermore, invasive species richness has decreased from a mean of 33 species to 25 species during the most recent two-year period. In addition, regeneration of native and outplanted native and exotic species increased significantly under the hybrid restoration. At the ecosystem level, some of the outplanted species had slow rates of leaf litter decomposition, which we suspect is leading to an overall reduction in the rate of nutrient cycling, a promising sign for further invasion resistance. We suggest that given adaptive management, hybrid restoration can be scaled to larger landscapes and other ecosystems as a strategy to sustain biodiversity in 21st century landscapes.

Challenges for Restoration of Invaded Hawaiian Wet Forest Ecosystems. Christy Martin*; UH PCSU/Coordinating Group on Alien Pest Species, Honolulu, HI (417)

The arrival of colonizing species via wind, birds, and ocean currents over the course of millions of years, coupled with Hawaii's geographic isolation and diverse physical environments led to more than 18,000 native plant and animal species and the world's highest degree of endemism--native species found nowhere else on Earth. Like on many islands, the endemic and indigenous species of the Hawaiian archipelago are particularly vulnerable to the effects of biological invasions. In the plant realm, the purposeful introduction of plants for forestry, food, ornamental, and other uses is the primary pathway for the arrival of non-native plants in Hawai'i, a small percentage of which become invasive species. The scale and scope of the invasion in Hawai'i is evident, from the proliferation of hundreds of species of invasive plants and near absence of native species in most lowland areas that receive between 500 and 6000 mm of rainfall. However, compared to some European landscapes where species have been moved around for thousands of years and questions of species native ranges are common, in Hawai'i the vast majority of non-native species arrived within the last 250 years. Despite the use of predictive modeling tools, commodity import risk assessments, the work of inspection agencies, and enhanced early detection/rapid response capacity, there is no indication that the invasion rate is decreasing, and the impacts of established invasive species continues to rise. Compounding the challenges of addressing invasion pathways and managing the impacts of existing invasive species is the X factor that is climate change. Restoration of wet forests in Hawai'i requires that we add new tools and technologies to the toolbox, and that we continue to apply good weed science, but it will also require multiple disciplines to work together in a more holistic approach to prevent new invasions and impacts.

Challenges for Restoration of Invaded Hawaiian Dry Forest Ecosystems. Susan Cordell*; Institute of Pacific Islands Forestry, USDA Forest Service, Hilo, HI (418)

Hawaiian dry forest ecosystems are amongst the most endangered ecosystems in the world. Loss of this ecosystem is primarily a result of wildfires fueled by invasive C4 grasses that have led to the loss of more than 90% of the lowland dry forests in Hawaii. These grasses now dominate the understory, resulting in the almost complete loss of native seedling recruitment, with cascading losses to forest structure. These changes in community structure and composition result in fuel and microclimate conditions that increase the likelihood of subsequent fires. This cycle is now considered the primary agent of forest to grassland conversion in dry plant communities in Hawai'i and elsewhere in the tropics. Land managers tasked to protect and restore these ecosystems face many challenges including aseasonal and unpredictable climate patterns, extreme abiotic stressors, slow growing native flora, loss of pollinators and dispersers, access to seed sources and propagation techniques, and management costs associated with maintenance of conservation units. Despite these challenges, focused dry forest restoration research over the past two decades has increased our effectiveness in restoring these systems. Techniques such as shading via fast growing understory plants to reduce C4 sun-loving grasses and using microtopography to inform habitat suitability for restoration such as focusing on downward facing slopes in leeward areas. Prioritizing weed management during wet years can reduce management costs and subscribing a plant functional trait approach to species selection will promote effective species assemblages. Combined, these techniques encourage resistant and resilient communities and are all strategies that can confer restoration success.

Hawaiian Invasions as a Call for Help for Invasions Throughout the Pacific Islands - What Hope is There for the Future of Island Ecosystems? David R. Clements*; Trinity Western University, Langley, BC, Canada (419)

Since western contact in 1779, hundreds of non-native plant species have been introduced to Hawai'i, and many of them have become exceedingly abundant, displacing native species. Scientists and managers have a long history of seeking ways to mitigate this invasion, but management efforts are often futile and under-resourced. This call for help is repeated across the Pacific Islands. In 2007 I co-founded with Curtis Daehler a series on "Biology and Impacts of Pacific Island Invasive Species" published in the journal Pacific Science. Papers published in the series on various invasive species provide further supporting evidence of the unique challenges that Pacific islands face, as evolutionary crucibles for endemic island species ill-equipped to deal with invasion by generalist invaders. The invasive plant mile-a-minute, *Mikania micrantha*, has spread to 23 Pacific island nations and impacts native plants through smothering and competition. Although not weeds, invasive animals like pigs, goats, cats or rats very much act like weeds in altering ecosystem function and reducing native species populations. Even invasive ants, though hardly noticed by human inhabitants, have fundamentally altered island ecosystems. Compared to Hawai'i, other Pacific island nations tend to be poorer which comes with the advantage of reduced risk of invasions via commerce, but the disadvantage of having fewer resources to manage invaders. Some hope lies in recognizing the common threat posed by invasive species to multiple islands, and developing management solutions that can be shared among the 33 or so Pacific island nations. World nations gathering to hammer out the Paris Agreement on climate change clearly heard the call for help from Pacific island nations threatened by rising sea levels. Similarly, we can hope that the call for help by Pacific island nations amidst the deluge of invasive species will also be heard.

Discussion. David R. Clements*[1], Curtis Daehler[2]; [1]Trinity Western University, Langley, BC, Canada, [2]University of Hawaii at Manoa, Honolulu, HI (420)

Abstract not available

SYMPOSIUM 2: The Role of Intelligent Machines in Weed Management

Introduction to Symposium. Sharon Clay*; South Dakota State University, Brookings, SD (421)

Abstract not available

Deep Learning and Weed Management - from Data Acquisition to Control of Herbicide-Resistant Weeds. William L. Patzoldt*; Blue River Technology, Sunnyvale, CA (422)

Deep learning is an emerging sub-field of artificial intelligence that allows computers to teach themselves how to solve problems. Using a variety of sensors, images can be collected from fields and used to teach computers how to differentiate plants. A deep learning workflow for crop and weed detection requires image collection, image processing, human labeling of images, model training, and model deployment to intelligent sprayers. When deep learning models are deployed on intelligent sprayers capable of precision applications (e.g. See & Spray™), the combination creates novel opportunities to control herbicide-resistant weeds. To demonstrate, a field trial was established in cotton (*Gossypium hirsutum*) at a site with a known population of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*). Treatments consisted of either a 1X or 0.5X rate of a PRE herbicide program using *s*-metolachlor at 1070 g ai ha^{-1} plus fluometuron at 840 g ai ha^{-1} (designated as the 1X rate), followed by several POST herbicide programs. The precision See & Spray herbicide POST program consisted of paraquat at 560 g ai ha^{-1} plus prometryn at 730 g ai ha^{-1} fb the same herbicides and rates 22 days later with or without broadcast partners that included glyphosate at 870 g ae ha^{-1} and/or acetochlor at 1260 g ai ha^{-1}. Precision See & Spray applications were compared with glyphosate at 870 g ae ha^{-1} plus acetochlor at 1260 g ai ha^{-1} fb glyphosate at 870 g ae ha^{-1}. When precision See & Spray applications where co-applied with broadcast applications of glyphosate plus acetochlor fb glyphosate, visual control of Palmer amaranth increased from 74% to 95% or 63% to 91% when using the 1X or 0.5X PRE program, respectively, with the 0.5X PRE program comparison being significantly higher (P=0.1; N=4). In these paired comparisons, the addition of precision See & Spray co-applied with the broadcast glyphosate program increased lint yield from 1379 kg ha^{-1} to 1437 kg ha^{-1} or 1366 kg ha^{-1} to 1401 kg ha^{-1} when using the 1X or 0.5X PRE herbicide program, respectively. While not a statistically significant increase in cotton lint yield within this trial, the increased yield by adding the precision See & Spray program component is consistent with the improved control of glyphosate-resistant Palmer amaranth. In summary, agriculture is rapidly increasing technology adoption to improve agricultural input efficiency and efficacy. Precision applications of herbicides using See & Spray enabled by deep learning is an example of how this technology can be used to create new options to enhance yield protection from the increasing threat of herbicide-resistant weeds.

Weed 4.0 - A Data-Driven Weed Science and Technology. Mohsen B. Mesgaran*; University of California, Davis, Davis, CA (423)

Industry is exhibiting an unprecedented megatrend towards automation propelled by sensing technology that generates massive amount of data, computational power that enable processing big data, and engineering solutions that can translate information into actions at high efficiencies. This ongoing evolution in industry is often referred to as Industry 4.0 representing the fourth revolution in the history of human since the discovery of steam power in 1780 i.e. the first industrial revolution. Where does weed technology stand on this rapidly evolving technological landscape? In the presentation, I strive to introduce the notion of “Weed 4.0” and how the small and big data along with cyber-physical merger are transforming the way we are doing weed science and technology.

Tackling the Herbicide Resistant Weed Crisis with Teams of Mechanical Agbots. Girish Chowdhary*; University of Illinois, Champaign, IL (424)

Abstract not available

Autonomous Weeding in Vegetable Crops. Thomas Palomares*; FarmWise, San Francisco, CA (425)

In-season weed control management in both organic and conventional vegetable crops mostly relies on labor-intensive hand weeding. However, in California, vegetable growers are reporting drastic labor shortages of field workers. Artificial intelligence (AI) and in particular deep learning, one of its nascent subsets, has been used in various industries for the detection of faces and objects. Applied to farming, this relatively new field is now enabling computers to self-learn how to recognize plant species from one another and distinguish characteristics of the identified plants (stem location, number of leaves, size, volumetric data). Mixed with robotics - another emerging technology that has been successfully leveraged in sectors such as the automotive industry and healthcare - computer vision is now opening the door to the development of innovative weed control tools. FarmWise has built a self-driving general robotic platform that mechanically weeds in-between the rows and in-between crops using crop-recognition capabilities and blades. Today, the machines work on leafy greens. Building generalized learning models that can detect a broad range of crops and weeds, and a robotic system that can effectively work in difficult soil types remain technical challenges facing these technologies today. Looking ahead, the same technologies carry the great potential to optimize pest control applications and enhance Pest Control Advisors' work by offering early detection of pest and diseases.

Economic Considerations for Automated Weed Management in Vegetable Crops. Laura Tourte*; University of California Cooperative Extension, Watsonville, CA (426)

Weed control in specialty crop production is labor intensive, labor costs are rising, and the availability of agricultural workers is declining. Hand weeding is an essential standard practice in lettuce production and represents roughly 40 percent of total weed management costs. Automation is often touted as a potential solution in whole or part to a worsening labor situation. However, economic considerations and impacts, when compared to hand weeding, are not well understood. Research to evaluate differences in ownership and operating costs, payback period and labor use and cost savings for four automated weeders were conducted during the 2017-2018 growing season. Hand weeding was reduced by 38 or 45 percent and resulted in a labor cost saving per acre. Labor use reductions and cost savings are greater for full season plantings and the industry in total. However, per acre ownership and operating costs for the automated technologies are substantial and show that their combined costs are roughly double that of hand weeding. Labor scarcity, cost, and the ability to perform timely field operations will ultimately factor into a grower's decision to purchase or deploy automated technologies.

Linkage Between Workforce Development and Precision Agriculture Diffusion. Scott Fausti*[1], Sumadhur Shakya[1], Sharon Clay[2], David Clay[2], Bruce Erickson[3]; [1]California State Univ. Monterey Bay, Marina, CA, [2]South Dakota State University, Brookings, SD, [3]Purdue University, West Lafayette, IN (427)

A national survey of precision agriculture (PA) retail dealerships was conducted in 2015. The survey included questions on dealership views of the importance of PA knowledge, skills, and abilities of their current or future PA employees across five job categories. A statistically significant finding indicates that as it becomes increasing more difficult to find qualified PA employees, the PA knowledge levels of potential employees' declines. The PA literature provides a series of stylized facts on the value of PA expert services as a facilitator of farmer PA adoption.

This set of stylized facts allows us to conclude that complexity and the lack of producer expertise are factors that do affect adoption rates in the U.S. and numerous other countries. In turn, these studies imply that if farmers had access to PA extension services and PA vendor expertise, then adoption rates would be higher. The retail dealership survey suggests that the lack of a qualified PA workforce may limit the ability of PA service industry to provide farmers with the technological knowledge to enhance PA adoption rates.

2D and 3D Vision Techniques for Crop Plant Detection in Mechanical Intra-row Weed Control. Lie Tang*; Iowa State University, Ames, IA (428)

Abstract not available

Machine Vision Systems for Automated Weeding - Current Technologies and Future Directions. Mark C. Siemens*; University of Arizona, Yuma, AZ (429)

Within the last decade, advancements in sensors, cameras and computing capabilities have led to the development of automated machines for thinning and intra-row weeding in vegetable crops. There are few reports in the literature about how these commercially utilized technologies work and why they are successful. Case study examples of machine vision systems for automated lettuce thinning and in-row weeding machines are provided. In short, these devices utilize downward facing cameras to capture images and computer algorithms to identify crop plants based on color, size and location. They cannot reliably differentiate between crops plants and weeds. For the case of weeding, this, coupled with their high cost and absence of a actuators capable of effective removal of weeds close to crop plants limits their utility, performance and widespread adoption. Research has been conducted for decades towards the development of techniques for crop/weed classification and numerous methods for a variety of sensors have been developed. The best performing systems provide only about 95% classification accuracy in real world conditions. More recently, artificial intelligence and deep learning have been employed as a technique to identify crop and weed plants. Based on a review of literature, crop/weed classification accuracy is comparable to conventional techniques, about 95%. Misclassification of levels of 5%, where crop plants are identified as weeds and targeted for destruction, is not economically viable in vegetable crops due to their high value. New technologies and approaches are needed. A review of literature points towards systems that combine 3-D morphology, optical color and accurate location data with deep learning techniques may be the most viable approach. Given the rapid advances in technology, it is likely that reliable crop/weed differentiation will be technologically possible. An important technical challenge that needs to be overcome is the development, integration and deployment of an economically viable and effective technique for precision weed removal in order for automated weeding machines to become a reality and utilized in production agriculture.

Precision Crop Protection: Soil Management Zones for Optimizing Weed Control Efficacy. Anita Dille*[1], Garrison J. Gundy[2]; [1]Kansas State University, Manhattan, KS, [2]Valent U.S.A LLC, Seymour, IL (430)

Soil application of herbicides for preemergence (PRE) weed control is vital for corn and grain sorghum production. The amount of herbicide bound to the soil, adsorption, strongly influences the amount active in the soil for weed control and is often correlated to soil organic matter (SOM) and soil texture. These soil factors can vary within one field, making it difficult for producers to follow label recommendations and achieve adequate weed control with a uniform rate. With precision agriculture technologies, variable rate applications (VRA) can be utilized to maximize herbicide effectiveness by applying the right rate in the right place. In 2016 and 2017, herbicide algorithms were developed for two different tank-mixes to be applied at nine locations across Kansas. A Veris MSP3 system was utilized to collect and develop interpolated maps of SOM and EC. EC values were correlated with soil texture and separated into coarse, medium, and fine-textured classification groups. Three algorithms were evaluated in the field for each tank-mix based only on SOM (alg-SOM), SOM and soil texture (alg-SOMtex), or a flat rate based on the average soil properties for the entire field. Rates for each tank-mix were based on the maximum usage rate (MUR) allowed. Morganville was the only corn location with adequate soil variability to see large differences in application rates. The amount of herbicide applied on average was higher with VRA compared to the flat rate in Morganville. Although more herbicide was used, increased weed control was achieved with alg-SOMtex (92%), compared to the flat rate (71%). For all grain sorghum locations, VRA reduced the average amount of herbicide applied compared to the flat rate. Alg-SOM achieved the same amount of weed control at 8 WAT as the flat rate, even with a lower rate. Alg-SOMtex reduced the herbicide load by 12% compared to alg-SOM at four of the five grain sorghum locations, and provided the same amount of weed control at 8 WAT, except at Hutch Redd in 2016. VRA of soil-applied herbicide was able to reduce herbicide load and cost for many locations, and also increase weed control when compared to a flat rate across variable fields. Using alg-SOM would require only one soil property to be collected and was able to reduce the herbicide load without decreasing weed control across all locations.

The Advent of Autonomous Solutions in the Management of Weeds, and its Impact on the Use of Chemicals for Precision Agriculture. Wade Robey*; Raven Industries, Sioux Falls, SD (431)

In the coming decade, farming as we know it will be revolutionized by the use of self-driving tractors and robots that can perform the time-consuming tasks now done by humans. This future-state is approaching quickly, and has the potential to be disruptive if not anticipated and met with new technologies to enable its effective implementation. Automation, communication and integration technologies are all coalescing around the premise of reducing the complexity of the farming solution, while increasing the functionality, efficiency and overall enterprise value of the machine platform(s) that execute the required tasks to get the job done. In addition, the ability to "stretch" the work-day around the clock will be a significant value-driver as labor shortages, and an ever-shrinking window of time to execute many of these required activities is often times difficult to predict and subject to temporal/regional weather conditions. Mechanization and automation in numerous industries has led to unprecedented efficiency and productivity throughout history. We believe that the total potential market for autonomy in agriculture will reach ~$6.5B USD by 2025. This growth initiates from a current market estimate which was based in 2019 upon an estimate of approximately 12K systems/units deployed world-wide (mostly small-limited function systems), and that which is forecasted to grow to ~61K systems in 2025, achieving a market growth CAGR of 25% over this period. We recognize that fully autonomous "unmanned" operations will not be the initial realization of this new state. Rather an evolution not revolution towards full autonomy is much more likely to be realized. Accordingly, technology providers will be able to mitigate investment risk by commercializing intermediate product and technology packages that will bring real present value, and also be the underpinnings of the platforms that will be needed in the future. Although each of the elements of the farming sequence are in their own right critical to the success of the overall enterprise, the cost/efficacy of spraying of agricultural chemicals is often a key driver. In recent years, new chemistries have offered new and sometimes improved-efficacy options, but have also brought with them issues related to drift, and to exposure to increased liability for improper application. Consumer concern with the use of chemicals on feed/food products has driven increased regulation, especially in the EU which has been a bellwether region with respect to predicting the future-state of regulatory intervention strategies. This has also led to a resurgence in mechanical weeding technologies that can offer viable alternatives to chemical applications. Automating agricultural spraying has been a long-term objective for technology providers, and end-users have been realizing the advantages of technologies for geolocation, auto-steering, boom height control and PWM spraying systems for turn compensation for many years. New technologies for vision-based row steering are bringing new value, and all of these advances have good synergy with automating the power platform as well. Whether a farmer chooses chemical or mechanical approaches to weed control autonomy will allow for sprayers to travel at slower speeds, improving the efficiency and efficacy of approaches for weed identification, and for spot spraying solutions. These technologies will complement the current use of direct injection systems which already allow for rapid chemical change, less chemical waste and reduced environmental contamination. In the future, automation will improve the efficacy of weed classification, and the possibility to realize the full value of chemical selectivity in real time to reduce weed persistence and the possibility of increased weed resistance.

Panel and Open Discussion. Steve Fennimore*; University of California, Davis, Salinas, CA (432)

Abstract not available

SYMPOSIUM 3: Genomics of Weedy and Invasive Species – 2025 and Beyond

Introduction to Symposium. Mithila Jugulam*; Kansas State University, Manhattan, KS (333)

Abstract not available

The International Weed Genomics Consortium: A Resource for Weed Genomics. Todd A. Gaines*[1], Sarah Morran[1], Paul Neve[2], Eric L. Patterson[3], Joseph S. McElroy[4], Roland S. Beffa[5], Mithila Jugulam[6], Patrick Tranel[7]; [1]Colorado State University, Fort Collins, CO, [2]Rothamsted Research, Harpenden, United Kingdom, [3]Michigan State University, East Lansing, MI, [4]Auburn University, Auburn, AL, [5]Bayer AG, CropScience Division, Frankfurt, Germany, [6]Kansas State University, Manhattan, KS, [7]University of Illinois, Urbana, IL (334)

The utilization of genomics to study weeds is expanding but remains limited by the lack of sequence resources for multiple weed species, and a lack of training among weed scientists to use genomics approaches. The potential application of genomic studies for weeds includes herbicide resistance, discovery of new herbicide targets, weed identification and diversity, the genetic basis of weedy traits, invasiveness, seed dormancy, allelopathy, biological control, and reproductive characters. Currently, close to ten weed species have a sequenced reference genome, in various stages of completeness. The International Weed Genomics Consortium (IWGC) has been established as a coordinated international effort in weed genomics and represents the community of scientists from academia and industry with interests in the genomics of weedy plant species. The vision of the IWGC is to 1) obtain high quality assembled reference genomes for the most important weed species worldwide; 2) to provide user-friendly genome analytical tools and user training through web-based databases and resources; and 3) to facilitate discussion and collaborations within this emerging field. The goal of the IWGC is to sequence the genomes of 10 weed species in 3 years, make the assemblies publicly available, and to train the weed science community in the use of genomics tools and databases. Participation from interested scientists is requested.

Systems Biology and Synthetic Biology Unite: Towards Elucidation of Non-target Herbicide Resistance Mechanism in *Conyza*. Charles Neal Stewart*, Cristiano Piasecki, Yongil Neal Yang, Bryce Trull, Reginald Millwood; University of Tennessee, Knoxville, TN (335)

Conyza canadensis (horseweed) represents one of the best-studied weedy species from a systems biology perspective. There are now two studies that have produced draft genome assemblies, which have provided the basis for additional -omics studies, some of which have been published. Updated -omics approaches to study the evolution of glyphosate resistance in *Conyza* point the way to a relatively short list of non-target resistance gene candidates that may be responsible for the evolution of resistant biotypes. As important as -omics data are to obtaining a better understanding of herbicide resistance evolution, we believe that synthetic biology technologies as well as high-throughput screening technologies will be needed to couple with systems biology to discover resistance genes as they evolve in weeds. Indeed, rapid and economic screening assays in plants have been made possible by combining robotics, reliable and relevant protoplast assays, and gene editing. We have begun to CRISPR-Cas9 gene edit ABC transporter gene candidates identified from -omics experiments on a protoplast platform followed by an efficient *Agrobacterium*-mediated transformation in horseweed The transformation procedure is effective in both glyphosate-resistant and -sensitive horseweed biotypes. The end-goal is to perform parallel gene editing workflows for knocking out candidate non-target resistance genes in resistant biotypes to render a susceptible biotype, which is needed for gene discovery validation.

New Tools to Investigate and Manipulate Black-grass (*Alopecurus myosuroides*). Dana R. MacGregor*; Rothamsted Research, Harpenden, United Kingdom (336)

Weeds successfully invade our agricultural land because of adaptations that allow them to survive weed control practices. Progress toward understanding which genes and cellular processes are required for these adaptations has been hindered by our inability to genetically manipulate weeds. Without GM techniques we have been unable to directly demonstrate specific genes are necessary or sufficient for an expected phenotype. We show here that in black-grass (*Alopecurus myosuroides*), loss- and gain-of-function studies are possible using virus-mediated transient expression techniques. Although these were developed for monocot crops, virus induced gene silencing (VIGS) reduces *PHYTOENE DESATURASE* expression and virus-mediated overexpression (VOX) drives GREEN FLUORESCENT PROTEIN in black-grass. Moreover, we demonstrate these techniques are applicable to testing herbicide resistance hypotheses in black-grass. VIGS against *AmGSTF1* demonstrates it is necessary for a resistant biotype to survive fenoxaprop application and heterologous expression of the *bialaphos resistance* gene with VOX is sufficient to confer resistance to an otherwise lethal dose of glufosinate. Black-grass is the most problematic weed for winter-cereal farmers in the UK and Western Europe as it has several adaptions that allow it to effectively avoid current integrated weed management practices. Black-grass also reduces yields and therefore directly threatens food security and productivity. Novel disruptive technologies which mitigate resistance evolution and enable better control over this pernicious weed are therefore required. These virus-mediated protocols offer a step change in our ability to alter genes of interest under controlled laboratory conditions and therefore to gain a molecular-level understanding of how black-grass can survive in the agri-environment.

Using Genomics to Investigate Dioecy in *Amaranthus* Species. Patrick Tranel*; University of Illinois, Urbana, IL (337)

Waterhemp (*Amaranthus tuberculatus*) and Palmer amaranth (*Amaranthus palmeri*) are successful weeds, in part due to their dioecious nature. Having separate male and female plants forces outcrossing, thereby fostering high genetic diversity and rapid adaptation. For example, numerous populations of both species have evolved multiple herbicide resistance, making them well adapted to agronomic fields in which herbicides are the primary means of weed management. To investigate dioecy in these species, we previously used restriction-site-associated DNA sequencing (RAD-Seq) of numerous males and females to identify sex-specific tags. Male-specific tags were identified from each species, consistent with previous evidence that males are the heterogametic sex. PCR-based DNA markers generated from a subset of the tags were highly reliable in distinguishing males and females. In our current work, we are using the male-specific tags to hone in on the male-specific region in recently obtained draft genomes of the two species. A surprisingly small number of annotated genes are shared between the male-specific regions of the two species, suggesting each species independently evolved dioecy. In a complementary approach to identify candidate genes important for dioecy, we are using transcriptomics to identify genes that are differentially expressed between males and females. In the short term, sex-specific markers can facilitate controlled crossing experiments (by enabling sex identity prior to flowering) and can be used in ecological studies to investigate sexual dimorphism and lability in the two species. In the long term, a better understanding of dioecy in these two weeds will inform strategies to manipulate sex, perhaps resulting in a novel weed control strategy.

Molecular Cytogenetic Analysis of Herbicide-resistant Weeds. Dal-Hoe Koo*, Mithila Jugulam, Bernd Friebe, Bikram S. Gill; Kansas State University, Manhattan, KS (338)

Fluorescence *in situ* hybridization (FISH), a molecular cytogenetic technique, is a DNA hybridization-based approach that generally uses directly-labeled fluorescent DNA probes to target specific chromosomal locations within the nucleus, resulting in colored signals that can be detected using a fluorescent microscope. Applications of FISH have been valuable to understand the possible basis of 5-enolpyruvylshikimate-3-phosphate synthase (*EPSPS*) gene amplification resulting in evolution of glyphosate resistance in some weed species. Although *EPSPS* gene amplification based glyphosate resistance has been confirmed in many dicot and monocot weeds, use of FISH technique provided fascinating and novel information about the mechanism(s) of amplification leading to the evolution of glyphosate resistance in weeds. The aim of this presentation is to provide an overview of gene amplification as a mechanism of herbicide resistance and to discuss the scope of use of molecular cytogenetic tools in weed science.

The eccDNA Replicon, Adaptive Potential, and Functional Genomics in *Amaranthus palmeri*. Christopher A. Saski*[1], William T. Molin[2]; [1]Clemson University, Clemson, SC, [2]USDA-ARS, Stoneville, MS (339)

Palmer amaranthus (*Amaranthus palmeri* (S) Wats.) is one of the most competitive weed species that threatens crop production across the U.S., and has several weedy traits that make it particularly aggressive. Palmer's dynamic genomic plasticity has endowed rapid adaption to several herbicide modes of action, including the molecule glyphosate. The causal mechanism of glyphosate resistance via *EPSPS* gene amplification and overexpression of the EPSP synthase, has been implicated as an extra-chromosomal DNA (eccDNA). Through single-molecule sequencing, we determined the sequence composition of the eccDNA to be 398kb and encodes the *EPSPS* gene and 58 other encoded genes whose functions traverse detoxification, replication, recombination, transposition, tethering, and transport. Gene expression analysis under glyphosate stress showed transcription of 41 of the 59 genes, with high expression of *EPSPS*, aminotransferase, zinc-finger, and several uncharacterized proteins. The genomic architecture of the eccDNA replicon is comprised of a complex arrangement of repeat sequences and mobile genetic elements interspersed among arrays of clustered palindromes that may be crucial for stability, DNA duplication and tethering, and/or a means of nuclear integration of the adjacent and intervening sequences. To study the function of candidated genes, a genetic transformation system was developed for Palmer using a modified floral dip procedure and was verified successful by expression of a fluorescent reporter gene.

The Genome of *Kochia scoparia*: A Story of Evolution in Action. Eric L. Patterson*[1], Todd A. Gaines[2], Christopher A. Saski[3], Philip Westra[2], Crystal D. Sparks[2]; [1]Michigan State University, East Lansing, MI, [2]Colorado State University, Fort Collins, CO, [3]Clemson University, Clemson, SC (340)

Kochia scoparia (kochia) is one of the most difficult to control weeds in the Western United States and Canada. Kochia has many extraordinary traits that make it exceptionally weedy. Chief among these are its many abiotic tolerance and resistance traits including drought, salt, cold, and in selected populations, herbicides. To begin understanding the genetics of these traits we embarked on sequencing the genome of kochia. The first draft of the kochia genome was published in October 2019 and this assembly consisted of 19,671 scaffolds, 711mb, and an n50 of 61 kb. Since that time, we have been working on a second draft of the kochia genome. We have collected deep PacBio Sequel Sequencing Data, Nucleosome positioning data, 3D chromatin conformation data, and an optical map. This second draft genome is still in progress; however, the current state of this genome consists of 65 scaffolds, 1,022 mb, and an n50 of 39.3 mb. Furthermore, we have used these genomes to look at copy number variation (CNV) of the 5-enolpyruvylshikimate-3-phosphate synthase (*EPSPS*) gene that confers resistance to glyphosate. We assembled the *EPSPS* locus from a glyphosate-resistant kochia plant by sequencing select bacterial artificial chromosomes. We compared the resistant and susceptible *EPSPS* loci and reconstructed the history of duplication of the *EPSPS* locus and uncovered the genes that are co-duplicated with *EPSPS*. The comparison between the susceptible and resistant assemblies revealed two dominant repeats which can be validated in several wild populations of glyphosate resistant kochia; however, not all glyphosate resistant plants have this repeat structure, indicating at least one other event leading EPSPS CNV in *Kochia scoparia.*

Canada Fleabane Genome Sequence. Martin Laforest*[1], Sara L. Martin[2], Eric R. Page[3]; [1]AAC-AAFC, St-jean-sur-richelieu, QC, Canada, [2]AAC-AAFC, Ottawa, ON, Canada, [3]Agriculture and Agri-Food Canada, Harrow, ON, Canada (341)

Canada fleabane is one of the most economically important weed species worldwide and infestation of herbicide resistant biotypes can result in significant yield losses across a range of cropping systems. As such, Canada fleabane has been the subject of many studies to understand how it has become resistant to herbicides. These studies have not yet identified a mechanism that explains non-target site glyphosate metabolic resistance. We have provided the first report of a chromosome-scale genome sequence for Canada fleabane. Third generation sequencing technology was used to create a genome assembly of 426 megabases, of which 9 chromosome-scale scaffolds cover more than 98% of the entire assembled sequence. This provides the information necessary to allow for the use of powerful genetic tools to detect and map the genes responsible for herbicide resistance. The knowledge gained with the aid of this new tool will be useful to create genetic tests for early diagnostic of resistance and, eventually, for control of this problematic weed. Additionally, the genome sequence will be a resource for studying genetic traits in asters, a large family that represents 10% of the diversity of flowering plants.

Symposium Discussion. Mithila Jugulam*; Kansas State University, Manhattan, KS (342)

Abstract not available

SYMPOSIUM 4: The Ecological and Biodiversity Impact of Invasive Grass Species and Their Management

Introduction to Symposium. Lisa J. Rew*; Montana State University, Bozeman, MT (278)

Abstract not available

Lehmann Lovegrass (*Eragrostis lehmanniana*) Ecological Impacts and Management Opportunities. Erik A. Lehnhoff*, Sherri Buerdsell, Andrew Dominguez, Nicole Pietrasiak; New Mexico State University, Las Cruces, NM (279)

Invasive grasses are economic and ecological threats to western US ecosystems as they alter fire regimes, displace native species and decrease rangeland forage value. Lehmann lovegrass (*Eragrostis lehmanniana*) is a South African C4 grass introduced to the southwestern US in the 1930s to restore degraded rangelands. It has drastically expanded its range and dominates many formerly diverse grasslands in the Sonoran and Chihuahuan Deserts. To evaluate invasive-native grass interactions and opportunities to restore lovegrass dominated landscapes we assessed (1) lovegrass and black grama (*Bouteloua eriopoda*) responses to altered climate, (2) legacy effects of lovegrass, and (3) impacts of targeted glyphosate application. In an experimental setting, extreme drought, represented by 80% reduced precipitation, negatively affected black grama and lovegrass equally. To test lovegrass legacy effects, we used soils from areas invaded by lovegrass for different lengths of time and implemented a plant soil feedbacks (PSFs) study incorporating a de Wit replacement series competition study with lovegrass and blue grama (*Bouteloua gracilis*). In uninvaded soils, lovegrass caused a negative PSFs on itself and blue grama, whereas in invaded soil PSFs were positive on both species, indicating that lovegrass PSFs would not negatively impact blue grama restoration. However, when grown together lovegrass was a superior competitor over native blue grama, and PSFs enhanced its competitive ability. In another experiment where lovegrass and black grama grew in mixed stands, glyphosate was used spot treat lovegrass. Over a two year period lovegrass mortality was minimal, but cover was decreased by 7% compared to the control whereas black grama cover increased in sprayed plots by 6% compared to the control. Results indicate that left unchecked, lovegrass will continue to negatively impact native grasses; yet, there are opportunities to reduce lovegrass dominance via targeted herbicide, and PSFs will not hinder restoration.

Reducing Invasive Grass Populations in Garry Oak Ecosystems Over the Long-term Via Mowing or Grazer Exclusion. David R. Clements*[1], Vanessa L. Jones[1], Joy Marconato[1], Emily K. Gonzales[2], Virginia Oeggerli[1], Jessica Brouwer[1]; [1]Trinity Western University, Langley, BC, Canada, [2]Parks Canada, Vancouver, BC, Canada (280)

Invasive perennial grasses degrade vulnerable Garry Oak ecosystems in the North American Pacific Northwest. Sweet vernal grass (*Anthoxanthum odoratum*) is one of the most abundant invasive grasses, forming monocultures in meadows once dominated by native perennial forbs (NPF). Success of sweet vernal grass is partly due to its invulnerability to grazing. Previous research showed that a combination of mowing and grazing prevention could potentially shift community composition, reducing the dominance of non-native grasses. We established 5 x 5 m plots in 2009 at Trinity Western University's Crow's Nest Ecological Research Area on Salt Spring Island, BC, Canada and tracked plant abundance over 10 years within four treatments: 1. fenced/mowed, 2. fenced/unmowed, 3. unfenced/mowed and 4. unfenced/unmowed. Our hypothesis was that long-term mowing, in the absence of grazing, will reduce the impact of non-native perennial grasses (NNPG) on Garry Oak ecosystem communities. A census of the vegetation was conducted annually and in 2016 we harvested plants to collect biomass data. Trends in percent cover over the first 7 years showed a decline in NNPG with mowing but no concomitant increase in NPF emblematic of the ecosystem. At the end of 7 years, the dry weight of NNPG in fenced/mowed plots was still highest among the plant functional categories, illustrating the inadequacy of a single mowing in August. In subsequent years we mowed in both early July and

August. In the ungrazed/mowed sites NNPG did decline, especially in 2019, but non-native annual grasses (NNAG) replaced NNPG, rather than native species. In all four treatments, native perennial graminoids (NPG) are generally on the rise, chiefly the sedge, *Carex inops*. However, the lack of NPF regeneration on the site illustrates another issue related to dominance of NNPG: lack of native propagules. Thus a holistic restoration effort would require extensive planting of native vegetation.

Plant Community Response Following Invasive Annual Grass Control in the Intermountain West. Corey V. Ransom*; Utah State University, Logan, UT (281)

Invasive annual grasses pose a monumental threat to much of the land area in Utah and the Western United States. In Utah, efforts have been mostly focused on management of downy and Japanese brome, medusahead, and ventenata. The recent discovery of ventenata in Utah has made it a top priority for management. In numerous trials over the past 14 years, it has been observed that control of invasive annual grasses and plant community responses vary widely depending on the existing condition of the treatment site at the time of treatment, the choice of herbicide, rate, and timing, and weather patterns during the length of the experiment or observation. While the response of plant communities to being released from competition can be amazing, in most of our locations, the plants that become prevalent after treatment are those that were present on the site prior to treatment. This is easier to observe for perennial plants on a given site, but much more difficult to predict for annual plants coming from the existing soil seed bank, that are not visible on the site at the time of treatment due to suppression by the invasive annual grasses. On highly disturbed sites which have been dominated by annual invasive grasses for years it is common to see a transition to a perennial species like field bindweed, or to annual species such as sunflower and prickly lettuce once the annual grasses are removed. Herbicide selection can heavily influence the species present after treatment based on species sensitivity to the herbicide used and the duration of invasive annual grass suppression. On sites with high presence of perennial vegetation, both native and improved species, community response is generally more positive and sustained. In these instances, the impact of the herbicide on the desirable species is more obvious and critical. For a herbicide providing a single year of annual grass control, perennial grass cover can increase or remain constant depending on whether the treatment is injurious or not. If the perennial grasses are suppressed by herbicide injury the first season after treatment and the annual grasses return by the next year, no positive perennial grass response may be observed. If a herbicide causes minimal injury to perennial grasses, a positive response may be observed the year after treatment, but not the next year after annual grass competition returns, especially if desirable plant densities are low. Longer suppression of annual grasses obviously allows for more perennial plant recovery. Experience with multiple treatments over a period of years also illustrates that plant community changes can be temporary, or more permanent depending on the ability of the existing plant community to capture available site resources. These research trials also demonstrated how multiple treatments over time can actually result in a degraded plant community, or shift the community to species not in line with management objectives. In some sites, invasive annual grass removal has resulted in minimal changes to plant richness the year after treatment, with increases in overall plant richness the second year after treatment for herbicides that continue to suppress the annual grasses. In a more intact plant community some treatments significantly reduced species richness, but the reduction was largely related to treatments controlling annual broadleaf and grass species. Native species richness was not reduced and the percent of weedy species comprising species richness was reduced by over 60%. In utilizing different strategies for invasive annual grass management, more information is needed about species response to individual herbicides and herbicide combination, as well as other management approaches. More guidelines on how to determine the community potential of a site, would greatly assist land managers in prioritizing which areas to manage and even what management tools to employ. Establishing longer duration research trials will allow identification of strategies that produce persistent and positive changes in plant communities.

Ventenata (*Ventenata dubia*) Management in Northern Mixed Prairie: Implications for Ecosystem Goods and Services. Marshall Hart*[1], Brian Mealor[2]; [1]University of Wyoming, Sheridan, WY, [2]University of Wyoming, Laramie, WY (282)

Ecosystem goods and services (EGS) are the benefits, both tangible and intangible, that humans receive from ecosystems. While we intuit that invasive species removal will improve or return benefits that were reduced by the invasive, this may not be the case. In northeast Wyoming, ventenata (*Ventenata dubia Leers. Coss.*) has recently invaded Northern Mixed Prairie. As part of concerted containment and control efforts, we can study the effects of ventenata management on this ecosystem. Our overarching objective is to evaluate the implications of ventenata management on the condition of EGS. More specifically, we focus on forage (quality and quantity) and plant species richness response to ventenata control. Over a two year period with separate sites each year, we sampled plots where ventenata had invaded and was subsequently controlled along with adjacent plots where ventenata had been left non-treated. We collected aboveground biomass by plant functional groups in July of 2018 and monthly throughout the growing season of 2019. We also recorded canopy cover (%) by species in July of both years. In 2018, we observed no differences in perennial grass biomass or species richness between treatments, although cover of western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love), the dominant perennial grass species, was higher in treated plots than in ventenata-dominated plots ($p<0.04$). However, perennial grasses were higher quality forage than ventenata by late July 2018 ($p<0.001$). We fit individual regression curves to annual and perennial grass biomass between treatments in 2019 data to evaluate relationships between seasonal biomass production and herbicide treatment. Peak perennial grass biomass was higher where ventenata control occurred than in non-treated plots. Annual grass biomass was nearly absent in treated plots. Species richness did not change with treatment in 2019 ($p=0.52$). These results have shed light on potential benefits of invasive species management while also highlighting that returning all EGS of an ecosystem may not be attainable with this single management approach.

The Impacts of Downy Brome (*Bromus tectorum*) on Pasture Forage Quality and Quantity in Colorado. Jacob Courkamp*; Colorado State University, Fort Collins, CO (283)

Downy brome may provide quality forage for livestock and wildlife while growing, but the brevity of this period of palatability, its variability from year to year, and the lack of forage variety in the areas it dominates suggest that diverse communities of native and perennial forages are likely superior. Previous research indicates that annual grass control following treatment with indaziflam (Esplanade, Bayer ©), can increase the biomass and richness of co-occurring native species, but the impacts of annual grasses on livestock forage quality are less well-understood. We assessed forage quality (crude protein, TDN, NDF, ADF, IVTDMD, and RFQ) and quantity at two sites in Colorado where different herbicide treatments were used to reduce downy brome. Sampling occurred in July 2019, the first growing season after treatment, and one treatment outperformed the others in terms of controlling downy brome (late post-emergence, indaziflam 73g ai/ha and glyphosate 354g ae/ha). Forage quality and quantity in these treatments were compared to untreated controls to assess the apparent forage impacts of downy brome. Treatment significantly increased forage biomass production at one of two sites, while results from the second site were complicated by a large post-treatment increase of Russian thistle (*Salsola tragus*). Across both sites, differences in forage quality were generally positive in the treated areas, but only increases in crude protein at one site approached significance. Our results indicate that downy brome primarily impacted forage quantity at our two sites in the first growing season following treatment.

Perspectives on the Ecological Impacts of Annual Grasses Across the Great Divide. Lisa J. Rew[1], Timothy S. Prather*[2]; [1]Montana State University, Bozeman, MT, [2]University of Idaho, Moscow, ID (284)

Impacts resulting from annual grass invasion depend, in part, on plant community changes across broad geographic ranges. Precipitation patterns west of the continental divide are drier in early summer than precipitation patterns east of the divide, summers are also hotter in the west. Montana and Idaho contain sage steppe vegetation with Idaho containing greater areas of Wyoming big sagebrush in contrast to Montana with limited Wyoming big sagebrush but with other subspecies such as big sagebrush and mountain big sagebrush. Wyoming big sagebrush communities are not as resilient with fire disturbance as other big sagebrush subspecies dominated plant communities resulting in greater negative impacts in Idaho contrasted with Montana. Residence time also affects the magnitude of negative impacts from specific invasive annual grasses. Downy brome (*Bromus tectorum*) was collected in 1898 in Montana and 1910 in Idaho where it has reduced native plant species diversity and perennial grasses decline as downy brome foliar cover increases. However for another annual grass, ventenata (*Ventenata dubia*), residence time is shorter. Ventenata found in 1956 In northern Idaho, and first collected in southern Idaho in 1986 while the earliest collection in Montana was Ravalli County in 1995. We infer residence time for ventenata is longest in the northern of Idaho and shortest in Montana. In northern Idaho, indicator species analysis suggests the nonindigenous annual bromes are not indicators for changes to ventenata foliar cover. However, where residence time is less, these same annual bromes are indicator species for ventenata. Perhaps with longer residence time, ventenata has displaced annual bromes where they co-occurred, and displacement has not occurred in southern Idaho nor Montana where residence times are shorter. Like downy brome, ventenata has decreased native plant diversity throughout Idaho as ventenata foliar cover increases. With any invasive annual grass that reduces native plant diversity, we should expect a cascade of other negative effects such as impacts to insect populations and larger animals that feed on insects, including birds. In northern Idaho, we have seen lower native insect abundance in areas with higher ventenata foliar cover. Those lower insect numbers impact birds that rely on insects such as swallows. Higher ventenata foliar cover reduced plant diversity with a subsequent decrease in flying insects. The reduce flying insect abundance changed egg laying and chick development leading to reduced numbers of birds leaving nests.

Invasive annual grass negative impacts range change to ecosystem function, plant diversity change, and animal diversity change each affected by climate and residence time. As we cross the divide, our climate patterns and annual grass residence times differ but the east may be experiencing a lag phase in ventenata invasion, and without preventative an adaptive management we may see similar negative impacts to biodiversity.

Bring Back Bees: Controlling Invasive Annual Grasses Restores Native Flowering Plants and Their Pollinators. Arathi Seshadri*; USDA ARS/WRRC/ISPH, Davis, CA (285)

Invasive winter annual grasses such as downy brome (*Bromus tectorum L.)* wreak havoc across the rangeland habitat of western United States. These highly competitive exotics are displacing native vegetation by depleting soil moisture and nutrients. As invasive grasses thrive in fragile rangelands, they lead to extensive losses in native plant diversity, which endangers and disrupts important ecosystem services including pollination. Pollinators, notably bees, are facing severe challenges associated with habitat-degradation-mediated depletion of nutritive pollen and nectar. Colorado is home to several species of native bees that have a longstanding mutualism with the flowering plants of the region. Controlling and eliminating invasive annual grasses can facilitate restoration and protection of native flora. Research efforts have resulted in the development of a new control option - Indaziflam (Esplanade® 200 SC), a cellulose biosynthesis inhibitor (CBI) herbicide. In parts of Colorado rangelands, treatments with Esplanade have resulted in multiple years of downy brome control and the release of many different species of flowering plants whose seeds were in the soil unable to germinate under the invasive downy brome competition. In this study, we compare Esplanade treated plots with non-treated controls to determine whether Esplanade can be used to control invasive winter annual grasses and reinstate diminishing floral resources and their bee pollinators. Treated plots exhibited a greater diversity of forb species than did control plots. The herbicide Esplanade (indaziflam) is effective at treating invasions of non-native annual grasses and restoring flowering forb species richness and diversity. Additional research is needed to determine the longterm efficacy of Esplanade, multiple applications may be needed to maintain forb diversity over longer time scales. It is also necessary to determine whether the chemical indaziflam will be taken up by the flowering plants and become available to pollinators collecting nectar and pollen.

Quail in the Grass: Controlling Cheatgrass to Enhance Nesting and Brood-rearing Habitat for Bobwhite Quail and Other Grassland Birds. Noe Marymor*; USDA-NRCS, Greeley, CO (286)

Northern bobwhite (*Colinus virginianus*) are a species of quail in serious decline across their range in the midwestern and southeastern United States. In eastern Colorado, northern bobwhite occur in sandsage rangelands, but their habitat quality is severely degraded in areas due to invasion of non-native invasive cheatgrass (*Bromus tectorum*). Experimental treatments to control cheatgrass using Indaziflam herbicide are on-going on the Bijou Ranch in Morgan County, Colorado. These experiments examine plant composition, diversity and bare-ground in treated and non-treated plots to determine what treatment impacts to northern bobwhite habitat may be.

Facilitated Discussion. Lisa J. Rew*; Montana State University, Bozeman, MT (287)

Abstract not available

SYMPOSIUM 5: Toxicology and Weed Science

Introduction to Symposium. Scott Senseman*; The University of Tennessee, Knoxville, TN (554)

Abstract not available

Risk Assessment and Management Review. Michael A. Hayoun*; University of California, Davis, Sacramento, CA (555)

Abstract not available

Data and Discernment: Glyphosate as a Case Study. Bernalyn McGaughey*; Compliance Services International, Lakewood, WA (556)

The human health litigation and conflicting accusations surrounding glyphosate with respect to its toxicity and potential impact on human health make an excellent case study of the partitioning between conclusions that are a result of balanced interpretation of toxicological data and verses those resulting from an agenda-driven, or at best uninformed-rumor-driven, interpretation of "risk". This presentation will explore these contrasts by putting them into perspective for the non-toxicologist. The scientific standards for risk assessment and how various types of studies and hazard endpoints fit within those interpretations made of glyphosate effects on humans will be explained. Additionally, the evolution of a pesticide "issue" under today's social-media setting, will be related to how other pesticide controversies have played out over time - even when the pesticide in question was not necessarily condemned by the data surrounding it. And finally, the heritage of an event such as this on the future use and public perception of glyphosate will be discussed.

The Glyphosate Issue: A Poor Man's Toxicology Viewpoint. Scott Senseman*; The University of Tennessee, Knoxville, TN (557)

Glyphosate ((*N*-phosphonomethyl)glycine) is an herbicide that was discovered in 1971 and registered for use in 1974. It has been used as a non-selective, foliar-applied herbicide as a burn-down application for many years prior to introduction into genetically modified crops (GMO's) in the mid 1990's. It has been used on more than 100 food crops over the course of it's registration and has multiple non-agricultural uses as well. In 2015, glyphosate was listed as a probably human carcinogen by the World Health Organization's International Agency for Research on Cancer (IARC). Since that time, there have been multiple law suits related to glyphosate that specifically cite glyphosate exposure as a cause for non-Hodgkins lymphoma (NHL). There have been multiple evaluations and reports that have been completed since the 2015 IARC report that suggest that glyphosate is an unlikely cancer risk including an evaluation by the Environmental Protection Agency that reaffirmed that their was no risk to public health by using the product. It is important to reemphasize that Risk = Hazard X Exposure when evaluating toxicological issues with any pesticide. Based on the existing data available, it appears that the toxicological risk associated with glyphosate remains very low. These risks include acute, sub-chronic, chronic, teratogenic and mutagenic toxicology data that has had multiple evaluations done spanning more than four decades. There have been questions regarding potential alternatives to glyphosate use that exist. However, they require planning, may be cost prohibitive and do not necessarily provide less toxicological risk than glyphosate.

How the Court System Handles Scientific Data and How an Expert Witness Presents Data in Court. Philip A. Banks*; Marathon-Agricultural & Environmental Consulting, Inc., Las Cruces, NM (558)

From time to time over the past 30 years, I have been called upon to provide expert testimony (affidavit, deposition or trial) on various types of investigations I've conducted. The process of how and why things are done in a certain way in a court of law is not always clear and how an expert can present data in support of their opinions varies from court to court. The Federal Rules of Evidence (Rule 702) requires that the expert be in compliance in these four areas: 1) the expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue; 2) the testimony is based on sufficient facts or data; 3) the testimony is the product of reliable principles and methods, and; 4) the expert has reliably applied the principles and methods to the facts of the case. An expert can be challenged in court as to whether they have adhered to all of these. In Federal Court, this is known as a Daubert hearing where the expert is asked questions in court related to their opinions. The expert can be challenged as to the following: 1) whether the theory or technique can and has been tested; 2) whether the theory or technique can and has been subject to peer review; 3) what is the known or potential rate of error; 4) what is the degree of acceptance in the relevant scientific community. The Judge is the "gatekeeper" and decides the outcome of the challenge. The Judge also decides on what evidence (or data) can be presented to the jury. All data or information, presented to the jury, comes from or is relied upon by the expert expressing the opinion(s). State courts generally follow the Federal Rules for evidence and allow for challenge either by Daubert or, in some states, a similar type of challenge that is usually less broad than the Daubert hearing. However, Federal Rule 703 does allow the following: "An expert may base an opinion on facts or data in the case that the expert has been made aware of or personally observed. If experts in the particular field would reasonably rely on those kinds of facts or data in forming an opinion on the subject, they need not be admissible for the opinion to be admitted. But if the facts or data would otherwise be inadmissible, the proponent of the opinion may disclose them to the jury only if their probative value in helping the jury evaluate the opinion substantially outweighs their prejudicial effect." While the rules for evidence appear to be clear in the Federal Rules, there is considerable variability in how Judges rule on similar evidence (data).

Getting and Staying Out of the Weeds When it Comes to Effectively Communicating Science. Norman Hammitt*; South College, Knoxville, TN (559)

The presentation is designed to illustrate how important it has become for scientists and researchers to learn how to better communicate their science to the non/scientific audience who will be greatly affected by the research being done. This understanding of the impact of simpler, more effective communication is especially important for those in agriculture whose work is essential to society's well-being and will continue to be for future generations.Already, efforts to engage graduate students in agricultural studies at the University of Tennessee Knoxville have shown positive results and has clearly defined for them the importance of these basic, yet necessary, skills.

Media Training Demonstration and Discussion. Scott Senseman*; The University of Tennessee, Knoxville, TN (560)

Abstract not available

Group Panel Discussion. Scott Senseman*; The University of Tennessee, Knoxville, TN (561)

Abstract not available

WORKSHOP: Building a Community to Battle the Wicked Problem of Herbicide Resistance

Building Communities to Battle the Wicked Problem of Herbicide Resistance. David R. Shaw*[1], Jill Schroeder[2], Michael Barrett[3], David E. Ervin[4], George Frisvold[5], Amy Asmus[6], Susan M. Koehler[7], Ian Burke[8], Mark VanGessel[9], Clint D. Pilcher[10], A Stanley Culpepper[11], Katherine Dentzman[12], Addie Mayfield[1], Jesaelyn Gizotti de Moraes[13]; [1]Mississippi State University, Mississippi State, MS, [2]New Mexico State University, Las Cruces, NM, [3]University of Kentucky, Lexington, KY, [4]Portland State University, Portland, OR, [5]University of Arizona, Tucson, AZ, [6]Asmus Farm Supply, Inc, Rake, IA, [7]USDA-APHIS, Columbia, MD, [8]Washington State University, Pullman, WA, [9]University of Delaware, Georgetown, DE, [10]Corteva AgriScience, Johnston City, IA, [11]University of Georgia, Tifton, GA, [12]University of Idaho, Moscow, ID, [13]University of Nebraska-Lincoln, West Platte, NE (609)

Abstract not available

DISCUSSION SESSIONS

Project 1 Discussion Session: Pasture, Range, Forest, Rights of Ways, Wildland, and Aquatic Invasive Plants

Moderators: Harry Quicke, Bayer and Shannon Clark, Colorado State University

Topic: *Opportunities for Mappying Invasive Weeds at a Regional Scale.*

The Weed Science Society of America and Western Society for Weed Science held a joint discussion session on Opportunities for Mapping Invasive Weeds at a Regional Scale.

Corey Ransom: Presence versus absence data is needed. How do we know if points reported represent a population or someone just did not scope out more of the area?

John Coyle: As a contractor or applicator, funding and time is a big deal. Ultimately who pays for the mapping? Landowners or persons paying contractor might look negatively on applicators being on technology/doing mapping instead of spraying.

Harry Quicke: What is the ability of the site to recover? There is a need to increase complexity of distribution mapping. There is currently a big push from Western Governors Association for using these maps.

Short discussion on concerns with making management decisions based on a map or by a person removed from doing the mapping.

At the end of the discussion, the Western Society of Weed Science session chair solicited nominations for the next Weeds of Range, Forests, and Natural Areas chair-elect. Scott Nissen nominated Will Hatler from Corteva for incoming co-chair. Byron Slough seconded the motion. Will Hatler was elected to serve as chair-elect in 2021 for Weeds of Range, Forests, and Natural Areas and agreed to accept the position.

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<u>Chair-Elect 2022:</u>
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Project 2 Discussion Session: Weeds of Horticultural Crops

Moderator: Jesse Richardson, Corteva, Mesa, AZ

Topic: *Encouraging Innovation Between Public Institutions and Industry.*

For the 2020 meeting, the weeds of horticultural crops section had 22 paper presentations that were well attended, with up to 47 participants at one time. The discussion session occurred on Tuesday, March 3 from 3:45 to 4:45 pm local time. The discussion topic title was "Encouraging innovation between public institutions and industry." Moderator: Jesse Richardson, Corteva.

The session was initiated by a short introduction of the topic by the moderator. This was followed by Ed Peachey making a short presentation on his experience in collaborating with industry in weed management within the broccoli production systems of Oregon. Following Ed's remarks, Brad Hanson made a brief presentation regarding a partnership that is being created at University of California in which an herbicide manufacturer is fully sponsoring a graduate student to answer key questions regarding a new herbicide active ingredient.

At that point, the group had a discussion regarding the roadblocks that seem to prevent collaboration between industry and academics. The issue of intellectual property came up as one of the primary reasons why chemical manufacturers are hesitant about these collaborations. It requires an investment of more than $300 million to bring an herbicide active ingredient from discovery to product launch. At the same time, universities are looking for new revenue streams. Attorneys for both groups often get involved in the process, and their goals are often found to be at odds with each other. Companies which are developing organic solutions for weed management often feel that they are left out of these types of collaborations altogether.

One of the topics that was presented as a possible topic for next year's session was, "Are biological solutions sustainable?"

A business meeting was conducted at the end of the discussion session, and Dr. Marcelo Moretti from Oregon State University was selected as the chair-elect for the 2021 meeting, which will lead to becoming the Horticulture chair in 2022. Dr. Harlene Hatterman-Valenti from North Dakota State University is content to serve as the Weeds of Horticultural Crops chair for the 2020 meeting in Boise, ID.

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Project 3 Discussion Session: Weeds of Agronomic Crops

Moderators: Misha Manuchehri, Oklahoma State Univeristy and Joseph Ikley, North Dakota State University

Topic: *Cultural & Mechanical Weed Management: What's Working?*

Cover Crops
Contributors: Mark VanGessel, Bill Curran, Bryan Young, Mark Bernard

Mark VanGessel: In the Mid-Atlantic, if cover crops are terminated earlier than 3 weeks before planting, there is not enough residue to benefit weed management. A longer growing season, plus 45 inches of rain per year make this region suitable for cover crops since there is plenty of time to establish in the fall, and moisture competition with cash crops is not an issue. Planting green in this region is adopted by growers because they only use one herbicide pass at planting compared to a 2-pass system (burndown prior to planting, followed by residual at planting).

Bill Curran: Residual herbicides used in crops generally do not affect growth of fall seeded cereal rye. Legumes and brassicas are more susceptible to carryover injury from herbicides applied in corn or soybean.

Brief discussion on tie up/interception of residual herbicides by living cover crop vs cover crop residues. Residual herbicides can be intercepted by heavy cereal rye residue (especially if roller-crimped) and limit activity in the soil. Bill Curran did not think there was much difference between green vs dead tissue. Kevin Bradley has a recent publication evaluating this question, but results were not discussed at this time.

Weed Chipped
Contributor: Michael Walsh

Michael Walsh discussed a new tool in Australia for selective weed control in chemical fallow. It is a tillage implement that senses green vs brown and will drop a tillage shank if green material is detected to "spot treat" weeds. Depth of the tines/shanks can be set to be more shallow or deep as needed. This implement works best in dry conditions so that weeds cannot re-root. The narrowest setting is 12 inches between the tines, so selective inter-row cultivation may be limited in cereal crops or other narrow-row crops. Current price is 250,000 Australian dollars for a 12-row unit.

Harvest Weed Seed Destruction
Contributors: Breanne Tidemann, Michael Flessner, Michael Walsh

Brief discussion about which weeds may be a fit for weed seed destruction at harvest. Breanne Tidemann mentioned that cleavers (catchweed bedstraw), foxtails, wild buckwheat, and kochia may be good candidates due to high percentage of seed retention at typical crop harvest. Wild oats only retain 30 to 80% of seed at small grain harvest. A switch to earlier maturing crops may allow harvest seed destruction of wild oats. Michael Flessner indicated that broadleaf weeds tend to have more seed retention than grasses at harvest. Michael Walsh indicated that in Australia, grower expectations must be managed when implementing harvest weed seed control. It typically takes 3 years of this practice before a noticeable reduction in weeds, and 5 years to make a significant contribution to reduction in weed seed bank. Fire for weed seed control was briefly discussed, but the general consensus is that fire can easily escape a field and is best avoided.

Tillage
Contributors: Bill Curran, Nevin Lawrence, Alan Helm, (I did not get the gentleman's name that brought up Ian Burke's research)

Discussion about the potential benefits of occasional (once every 5 to 10 years) moldboard plowing for annual ryegrass control. Several in the group noted that there is some success, and it is generally not too detrimental to soil benefits from long-term no-till. Bill Curran mentioned that moldboard plowing is better than more shallow tillage or cultivation for control of Canada thistle and field bindweed. Nevin Lawrence shared anecdotal evidence from the research station in Western Nebraska that Palmer amaranth and kochia are more problematic in no-till systems on the farm than conventional tillage. In a long-term tillage-comparison trial, glyphosate-resistant kochia was only found in the no-till plots. Kochia could be found in reduced tillage and deep tillage plots, but the kochia was not glyphosate-resistant.

Nevin Lawrence also mentioned that there has been some success using a rotary how in small grains for early-season weed control. Ian Burke's research was brought up that demonstrated good weed control utilizing interrow cultivation in no-till wheat production. Wheat rows were 10 to 16 inches wide in that research, which allowed for interrow cultivation. Alan Helm discussed how long-term no till in more arid regions led to soil compaction, so there was an overall benefit to occasional tillage to alleviate soil compaction.

Business Meeting

Misha Manuchehri nominated Nevin Lawrence for incoming co-chair. Breanne Tidemann seconded the motion. Nevin Lawrence agreed to accept the position. Meeting was adjourned.

<u>Chair 2020:</u>
Misha Manuchehri, Oklahoma State Univeristy, 371 Agricultural Hall, Stillwater, OK 74078
misha.manuchehri@okstate.edu

<u>Chair-elect 2021:</u>
Joseph Ikley, North Dakota State University, PO BOX 6050, Fargo, ND 58108-6050
joseph.ikley@ndsu.edu

<u>Chair-elect 2022:</u>
Nevin Lawrence, University of Nebraska, Scottsbluff, NE 69361
nlawrence2@unl.edu

List of Attendees not available

Project 4 Discussion Session: Teaching and Technology Transfer

Moderators: Thomas Getts, UC Cooperative Extension and Sandeep Rana, Bayer CropScience

Topic: *What Do You Wish Graduate School Would Have Taught You?*

The session ranged from 30-44 attendees throughout the afternoon. By the time the discussion session occurred, attendance dropped towards the lower end of the range. Chairs Sandeep Rana and Thomas Getts led the discussion. Initially the conversation focused on what technological aspects could be lacking in graduate school to prepare students for new developments in weed science. Introduction and emphasis of the discussion was on how changes in technologies available to research could leave current graduate programs unable to produce students capable of using these tools without further training.

Specifically, technologies with computer science, software, and remote sensing in relation to drones, robotics and smart robotic weeders were mentioned. Likewise, current developments in breeding and genomics, are fields weed science students may not be getting enough exposure to be proficient in their duties after school.

The feel from the audience/participants was that much of what was needed on the job would require a steep learning curve. Often the skills needed should not, or cannot, be developed in schools, but should be learned on the job. However, four aspects or skills were focused on for developing more prepared students thought their training:

- Bookkeeping is an essential skill that is often not learned in school. Graduate schools do not necessarily teach students how to manage budgets associated with grant projects or how to manage multiple budgets in concert. Developing and allowing students to gain understanding on best bookkeeping practices and fund management could make life easier after school.
- Human resources is a skill often not required of graduate students. After school, positions often require a supervisory role, and understanding how to manage people can be quite challenging. While probably a skill needed to be learned on the job, it is still an aspect needed for many positions after graduate school.
- Communication to all types of audiences, and general communication skills between colleagues was another topic. While graduate school does a good job of teaching communication to peers, and in scientific literacy, it often falls short of teaching general communication skills for the public and non-expert peers.
- Photography and taking good quality pictures and videos was another skill participants should come out of graduate school with.

One participant indicated that bookkeeping, communication, and photography should all be skills acquired before graduate school in undergraduate curriculum.

Near the end of the discussion, a counter argument/question was proposed: “What would you leave out of a graduate program to make room to learn one of these new skills?” Most participants in the audience did not have aspects of their graduate training, which they did not feel were beneficial. Few examples were given of what is currently included in weed science graduate programs that should be left out. It appeared that learning any additional skills would need to be in addition to the programs already in place, which is a trade off in its own right. Overall it was a beneficial discussion.

Chair-elect:
Floor was opened for chair/co-chair nominations.

WSWS - Breanne Tidemann was nominated and elected to serve as chair in 2022.

WSSA - Dawn Refsell was nominated and elected as co-chair for 2021. Since WSSA didn't have any co-chair from last year, Sandeep Rana volunteered to serve as chair for another year.

<u>WSWS Chair 2020:</u>
Thomas Getts, UCCE, 707 Nevada Street, Susanville, CA 96130
tjgetts@ucanr.edu

<u>WSWS Chair-elect 2021:</u>
Chris Mayo, Bayer CropScience, 625 Plum Creek Circle, Gardener, KS 66030
christopher.mayo@bayer.com

<u>WSWS Chair-elect 2022:</u>
Breanne Tidemann, Agriculture and Agri-Food Canada,6000 C&E Trail,Lacombe, Alberta T4L 1W1
breanne.tidemann@canada.ca

<u>WSSA Chair 2020:</u>
Sandeep Rana, Bayer CropScience
sandeep.rana@bayer.com

<u>WSSA Chair-elect 2021:</u>
Sandeep Rana, Bayer CropScience
sandeep.rana@bayer.com

<u>WSSA Chair-elect 2021:</u>
Dawn Refsell, Valent USA, 4811 SE 104th St, Runnells, IA 50237
dawn.refsell@valent.com

List of Attendees not available

Project 5 Discussion Session: Basic Biology and Ecology

Moderators: Caio Brunharo, Oregon State University, Corvallis, OR; Neeta Soni, Colorado State University, Fort Collins CO; Adewale Osipitan, University of California, Davis, Davis, California, CA

Topic: *How can we apply basic herbicide resistance knowledge to weed management practices?*

Herbicide resistance is one of the main research topics nowadays in the weed science literature. In fact, in the Basic Biology and Ecology session of the 2020 WSSA/WSWS Annual Meeting in Maui, HI, more than one third of the papers presented covered this topic. The intent of this discussion session was to gather different experiences from participants from around the world and understand how different cropping systems and extension networks are bridging basic herbicide resistance knowledge with applicable solutions to growers.

The first part of the discussion emphasized the roles of extension in working closely with growers to ensure herbicide resistance is properly managed, where growers should be aware of herbicide resistance presence in their fields and should be trained on the best management practices. It was pointed out that, in Australia, an effective system is in place, where growers can submit a suspicious herbicide resistant weed sample before the herbicide application is performed. Alternative herbicides are also tested and summarized in a report for growers showing which herbicides are still effective; thus, they would save money by using the remaining effective herbicides. Comments were made that it is important for growers to know which weeds are potentially more likely to be herbicide resistant in an area, so they are better prepared to identify herbicide failures in the field. In contrast, it was pointed out that this testing system is not as developed in the United States compared to Australia, and depends widely on what state you are in. In California, for example, such a system exists and is funded by the rice commission, and tests are available free of charge. However, there is no such testing service for other crops provided by the university systems. In New York, county agents work with growers to test samples in the weed identification lab at Cornell University. The recommendation moving forward is that an efficient testing system should be in place (preferably subsidized by the government/industry/commodity groups) to increase knowledge and awareness about herbicide resistant among growers. More training at the local level is also necessary so growers can identify when lack of control might be due to herbicide resistance.

Considerations regarding the economical sustainability of the production systems and farmer choices were made. Specifically, farmers sometimes worry that the identification of herbicide resistant populations in their fields may interfere with their profits. An example was given where growers might receive a lower grain price at the elevator if herbicide resistant Palmer amaranth seed contamination is present. Another limitation for weed scientist is the collection of weed populations for further research. Depending on the state in the United States, weed scientists are not legally allowed to collect samples in grower's fields without their authorization.

Other professional societies, food science societies in particular, are strongly concerned with the sustainability of cropping systems, but mostly focused on soil carbon, water quality, and soil health. However, herbicide resistance in rarely a topic of discussion. It was brought up that weed science discipline should work more closely with food companies to raise awareness from the consumer on the challenges that weed resistance pose to growers, especially vegetable growers.

Studies on the social aspects of grower decision making are necessary, because weed scientists seem to be more focused on the biological, ecological, and agronomic aspects of the weed, but put less efforts in understanding the social context of how farmers make their decisions. Economic analysis tailored to herbicide resistance management practices would be beneficial to better inform growers, with long term benefits of being proactive versus reactive.

Chair 2020:
Caio Brunharo, Oregon State University, Crop Science Department, 3050 SW Campus Way, Corvallis, OR 97331
Caio.brunharo@oregonstate.edu

Chair-elect 2021:
Neeta Soni, Colorado State University, 300 W. Pitkin, Fort Collins, CO 80523
neeta.soni@colostate.edu

Chair-elect 2022:
To Be Determined

Attendees:

Name:	**Affiliation:**	**Email Address:**
Gurjeet Gill	The University of Adelaide	gurjeet.gill@adelaide.edu.au
Eugene Law	Cornell University	epl49@cornell.edu
John Lindquist	University of Nebraska	jlindquist1@unl.edu
David Brunton	The University of Adelaide	david.brunton@adelaide.edu.au
Dana MacGregor	Rothamstead Research	dana.macgregor@rothamsted.ac.uk
Alicia Merriam	The University of Adelaide	alicia.merriam@adelaide.edu.au
Neeta Soni	Colorado State University	neeta.soni@colostate.edu
Adewale Osipitan	University of California, Davis	oosipitan@ucdavis.edu
Debalin Sarangi	University of Wyoming	dsarangi@uwyo.edu

WESTERN SOCIETY OF WEED SCIENCE NET WORTH REPORT

April 1, 2019 through March 31, 2020

ASSETS	
Cash and Bank Accounts	
American Heritage Checking	$11,790.97
American Heritage Money Market	$83,095.54
CD#3	$25,463.95
CD#4	$25,351.23
CD#5	$0.00
CD#6	$25,603.60
CD#7	$25,730.26
TOTAL Cash and Bank Accounts	$197,035.55
Investments	
RBC Dain Rauscher Account	$176,847.88
TOTAL Investments	$176,847.88
TOTAL ASSETS	$373,883.43

WESTERN SOCIETY OF WEED SCIENCE CASH FLOW REPORT

April 1, 2019 through March 31, 2020

INFLOWS ($)	
Annual Meeting Income	861.00
Capital Gains	137.41
Interest Income	692.25
Dividend Income	3,748.24
Miscellaneous Income	10,567.12
Membership Dues	1,639.95
Royalty for Proceedings Or RPR	430.24
Security Value Change	-19,755.68
Student Travel Account	1,702.20
Sustaining Member Dues	13,200.00
TOTAL INFLOWS	13,222.73
OUTFLOWS ($)	
Annual Meeting Filing Fee	375.00
Annual Meeting Expense	71,896.88
Bank Charge	1,267.01
Virtual Terminal Fee	123.91
CAST Annual Dues	1,500.00
Copies	121.10
Fee Charged	1,412.49
Insurance	500.00
Management Fees	22,009.10
Miscellaneous	2,628.56
Proceedings/Publications	1,500.00
Postage	7.85
Summer Meeting	4,941.18
Student Awards	3,985.65
Taxes	70.00
Travel to Summer Meeting	1,481.58
Travel to WSWS Meeting	1,204.53
Web Site Hosting	4,000.00
Web Site Design	2,000.00
Weed Olympics	7,134.86
TOTAL OUTFLOWS	128,159.70
OVERALL TOTAL	$-114,936.97

WSWS 2020 FELLOW AWARDS

Fellows of the Society are members who have given meritorious service in weed science, and who are elected by two-thirds majority of the Board of Directors.

Traci Rauch - Fellow Public Sector, University of Idaho

Traci Rauch completed her bachelor's degree in Biology at Pacific Lutheran University in 1992 and her Master of Science degree at the University of Idaho in 1998. Traci started her career in weed science as a Scientific Aide in 1995 and is currently a Research Associate at the University of Idaho. She conducts field and greenhouse experiments in the agronomic weed science program. Traci has been an active member in the Western Society of Weed Science since 1993. She has authored/coauthored 245 WSWS Research Progress Reports, 30 WSWS Proceedings Abstracts, 8 other professional abstracts, 3 Weed Technology articles, and has been WSWS Proceedings co-editor for 6 years, and WSWS Research Progress Report editor or co-editor for 9 years. She has presented at 152 other meetings and field tours. Growers and industry personnel seek her out for consultation on weed control in wheat, legumes, seed crops and other commodities. She has helped train graduate students at the University of Idaho since the mid-1990's.

Monte Anderson - Fellow Private Sector, Bayer Crop Science

Monte Anderson originates from a South Dakota wheat, corn, and livestock farm. He obtained B.S. and M.S. degrees in Agronomy from South Dakota State University, and got his first exposure to the weed science societies as a grad student at three NCWSS conferences. During his 36 years in industry he has worked for and survived five company names. Starting out with one of the smallest companies in 1984 and now with the largest company, Monte has worked on more crops and chemistry than he could ever imagine. He has presented on a wide variety of herbicides at the NCWSS, WSWS, and WSSA meetings. Starting out with American Hoechst as a R & D/Tech Service associate, he covered the Red River Valley of ND and MN. As Hoechst- Roussel Agri-Vet he covered 5 ½ states based out of Spokane, WA as a Field Technical Group representative, that's when he first joined the WSWS in 1985. When Hoechst Roussel Agri-Vet teamed up with NorAM to become AgrEvo, he was asked to work with transgenic corn and soybeans, essentially the Liberty Link technology, based out of eastern Nebraska. The advent of combining AgrEvo and Rhone Poulenc as Aventis brought him back to the Pacific Northwest and back to the Western Society of Weed Science. Then, when Aventis was sold to Bayer, Bayer CropScience has let him stay right where he was to work on almost anything. Then as Bayer acquired Monsanto, now he truly does cover anything and everything it seems! Last fall, Bayer CropScience assigned him a position as a Field Agronomist in the Field Solutions group that develops only the new stuff, but finds his experience with the old stuff is going to keep him fully engaged for some time until its no longer fun. He's currently a Principal Scientist residing near Spokane, WA covering WA, OR, and ID.

WSWS 2020 HONORARY MEMBER

William Price, University of Idaho

I was raised in New Mexico, Colorado and Florida. In 1981 I graduated from Colorado State University with a degree in Entomology. During my undergraduate work, I was introduced to field research and weed science through Dr. Ed Sullivan and Keith Haggenson at Great Western Sugar Beet Company. in Longmont, Colorado. Following graduation, I worked at the New Mexico State University Research and Extension center in Farmington, New Mexico under Dr. Rick Arnold. During this time, I gained experience in weed science, entomology, horticulture, soil science, and agronomy in a wide array of crops and production methods in association with the Navajo Agricultural Products Industries (NAPI). In 1987, I returned to school at New Mexico State University for my MS degree in statistics under Dr. Leigh Murray and Dr. Scott Urquhart. I also minored in soil science. In 1990, I moved to Moscow, Idaho to serve as a consulting statistician in the College of Agricultural and Life Sciences at the University of Idaho. In 1999, I received my PhD in Plant Science (Thesis on Quantitative Weed-Plant Competition models) under Drs Don Thill and Bahman Shafii. I have now worked on the other side of the research desk helping faculty, staff, and graduate students with statistical matters for nearly 30 years and in 2017, I became Director of Statistical Programs, College of Agricultural and Life Sciences, University of Idaho.

WSWS 2020 OUTSTANDING WEED SCIENTIST AWARDS

Vipan Kumar

The Outstanding Weed Scientist, Early Career was awarded to Vipan Kumar. Dr. Vipan Kumar is an assistant professor in the Department of Agronomy at Kansas State University. His specialization is in basic and applied research on herbicide-resistant weeds. He completed B.S. degree in crop science at Punjab Agricultural University, his M.S. in agronomy at Louisiana State University, and his Ph.D. in plant science at Montana State University, followed by a post-doc at MSU. His research goals are to evaluate and develop integrated weed management strategies for irrigated and dry land cropping systems. Projects in his research projects include management strategies for herbicide resistance species. In his short 3 years at KSU, he has brought in nearly $1.4 million in extramural grants. Dr. Kumar mentors a variety of people including undergraduate students, 3-4 graduate students, and 2 visiting scholars/postdocs.

Timothy Harrington

The Outstanding Weed Scientist, Public Sector was awarded to Timothy Harrington. Dr. Tim Harrington is the Insects, Pathogens, & Stressors Team Leader for the United States Forest Service Threat Characterization and Management Program in Olympia, Washington. He completed his B.S. in botany at Louisiana State University, his M.S. in forest ecology and Ph.D. in silviculture at Oregon State University. Dr. Harrington began his career as an assistant professor at Oregon State University and the University of Georgia, where he became a tenured associate professor, before going to work with the USFS in 2002. Throughout his career he has worked to develop research to enable foresters to manage the effects of undesirable plants and maximize commercial market potential and to assist public land managers in controlling invasive species to maintain native forest ecosystems. Dr. Harrington had an active role in creating modeling systems (PSME, VEGPRO, and CLUMP) and has published over 138 publications and is a co-author of the first textbook on silviculture and ecology of western US forests.

Marty Schraer

The Outstanding Weed Scientist, Private Sector was awarded Stephen M. Schraer. Dr. Marty Schraer is a Senior Scientist in Field Development at Syngenta Crop Protection. He completed his B.S. and M.S. in entomology at Texas A&M University and his Ph.D. in weed science at Mississippi State University. He started his career as an associate field research scientist with Zeneca Ag Products in 1999 before starting work as a research and development scientist with Syngenta Crop Protection in 2001. He has been responsible for developing 10 commercially available products and been influential in the development of dozens of other products including herbicides, fungicides, insecticides, and seed treatments. His dedication to maintaining high standards and producing quality research led him to become a member of the Data Quality Team at Syngenta Crop Protection which sets standards for design, data analysis, and reporting.

WSWS 2020 WEED MANAGER AWARD

Steve Sauer

The Weed Manager was awarded to Steve Sauer. Mr. Sauer is the County Weed Coordinator for Boulder County Parks and Open Space in Boulder County, Colorado. He completed his B.S. in agriculture education at Southern Illinois University. He started his career as a high school vocational agriculture teacher in Yorkville, Illinois in 1973 before turning to farming in Central Illinois and later the San Luis Valley in Colorado. In 2005, he began working for Boulder County Parks & Open Space and became the County Weed Coordinator in 2007. In his role, Mr. Sauer manages invasive species on over 100,000 acres of open space and 685 miles of county rights-of-way. Beyond managing invasive species, he has implemented a research program that has shown the benefits of invasive species management on ecological systems including mule deer and pollinator habitat and fire frequency reduction. He also conducts teaching and training for local agency personnel. His advocacy for invasive species management in open spaces and rights-of-way has impacted and expanded efforts of weed managers throughout the state.

WSWS 2020 PROFESSIONAL STAFF AWARD

This award was not conferred in 2020

WSWS 2020 PRESIDENTIAL AWARD OF MERIT

Marty Schraer

Marty Schraer received the WSWS Presidential Award of Merit from Pat Clay at the 2020 annual meeting in Maui, Hawaii.

WSWS 2020 ELENA SANCHEZ MEMORIAL STUDENT SCHOLARSHIP RECIPIENTS

Lesley Beckworth, Awards Committee Chair announce the recipients of the Elena Sanchez Memorial Scholarhsip were Hudson Takano, (Colorado State University), Jaycie Arndt, (University of Wyoming), and Hanah Huhns (University of Wyoming). A big thanks to their advisors for bringing along such great promising talent for the future of weed science.

WSWS 2020 RITA BEARD ENDOWMENT STUDENT SCHOLARSHIP RECIPIENTS

The Rita Beard Endowment Foundation Board of Trustees have selected three travel award scholarship recipients for 2020. They are Jaycie Arndt, an M.S. graduate student at the University of Wyoming; Michelle Majeski, an M.S. graduate student at Montana State University; and Alexandra Stoneburner an M.S. graduate student at Colorado State University and National Park Service intern. The Rita Beard Endowment Foundation is a 501 (c) (3) non-profit that was created from a generous donation from Rita Beard's family and friends to support students and early career invasive species managers with educational opportunities by providing registration and travel to professional meetings including: Society for Range Management, Western Society of Weed Science, Western Aquatic Plant Management Society and the North American Invasive Species Management Association. This year's winners will be attending the Western Society of Weed Science annual meeting (a joint meeting with the Weed Science Society of America) in March. To read more about the Foundation, learn how to apply for the 2021 scholarships, or make a donation go to: **http://www.wsweedscience.org/rita-beard-endowment-foundation/**.

Jaycie Arndt, University of Wyoming

My interest in invasive species began as a child on my family's ranch where I grew up loathing invasive species and yearning for a way to manage them. My education has given me the knowledge and the motivation to be a lending hand in the fight against invasive species. My research focuses on the impact of relative early emergence and growth rates of cool-season bunchgrasses on priority effects with invasive grasses. Hopefully, my research will assist management decision making and restoration efforts of western rangelands. My professional goal is to be an educator to the public and students about the management of rangelands so that we may act collaboratively, intelligently, and efficiently.

Michelle Majeski, Montana State University

I am a master's candidate at Montana State University and will defend my thesis in Spring, 2020. My research is focused on the biology of non-native winter annual grasses to prevent further invasion in range and pasturelands. After receiving a master's degree in Land Rehabilitation, I would like to work as an invasive species plant ecologist at an agricultural research station, providing information and tools to land managers to reduce invasive plants.

Alexandra Stoneburner, Colorado State University; National Park Service

I began working with invasive species when I started an internship with the Invasive Plant Program of the National Park Service as an undergraduate student. During this time, I was introduced to the complexity of invasive species management and my interest was pique. While working in this position I was simultaneously being introduced to the world of rangeland management. It was the marriage of invasive species and rangeland ecology that ultimately solidified my desire to pursue a career that meshes these disciplines. As a result, I began a master's degree in rangeland ecosystem science at Colorado State University. My research has centered around an invasive aquatic iris - yellow flag iris (*Iris pseudacorus*) and the ability to link results observed from field studies to the molecular mechanisms driving plant responses to disturbance. Over the last three years I have continued to work within the NPS Invasive Plant Program while also working towards the completion of my master's degree. The production of knowledge between researchers, managers, and practitioners related to invasive species especially in the context of rangelands, is where I hope to direct my career.

WSWS 2020 STUDENT PAPER AND POSTER AWARDS

With the joint 2020 meeting, the WSWS held a student paper contest while the poster contest was held in combination with the WSSA (**WSSA Spring Newsletter**). The 2020 WSWS graduate student paper contest had a total of 33 contestants and 15 judges volunteered their time. All contestants exhibited exceptional quality and professionalism and participants are to be commended. In accordance with WSWS operating procedures, the number of winning places in different sections varied depending on the number of students that participated in each section. Students in the paper contest were divided into five sections with 33 entries.

CLINT BEIERMANN

JODIE CROSE

MIRELLA ORTIZ

JAKE COURKAMP

NATHAN HAUGRUD

PRAGYA ASTHANA

MARCELO FIGVEIREDA

OLIVIA E. TODD

Not Pictured: Justin Childers

Weeds of Agronomic Crops:

- 1st – Clint W. Beiermann, University of Nebraska-Lincoln, *"Herbicide Potential for Palmer Amaranth Control in Sugarbeet, Selectivity of Desmedipham and Phenmedipham"*.
- 2nd – Justin Childers, Oklahoma State University, "*Non-tolerant Wheat Response to Quizalofop-P-ethyl in Central Oklahoma*".

Pasture, Range, Forest, Rights of Ways, and Natural Areas:

- 1st – Jodie Crose, University of Wyoming, "*Influence of Seeding Depth on Native Species Establishment in the Presence of Indaziflam*".

- 2nd – Mirella Ortiz, Colorado State University, "*Florpyrauxifen-benzyl: A Novel Auxin Herbicide for Aquatic Plant Management*".

- 3rd – Jake Courkamp, Colorado State University, "*Long-term Downy Brome (Bromus tectorum) Seedling Reduction with Indaziflam in Sagebrush-Grassland Plant Communities in Sublette County, WY US*".

Weeds of Horticulture Crops and Integrated Weed Management:

- 1st – Nathan Haugrud, North Dakota State University, *"Inter-row Cultivation Integrated with Residual Herbicide Programs in Sugarbeet*".

Basic Biology and Ecology:

- 1st – Pragya Asthana, Washington State University, "*EPSPS Gene Amplification Confers Resistance in Bromus Tectorum (Downy Brome)*".
- 2nd – Marcelo Figveireda, Colorado State University, "*Escaping Proteolysis: A 27 Base Pair Deletion in Aux/IAA2 Degron Tail Confers Resistance to Auxinic Herbicides in Sisymbrium orientale*".

Physiology:

- 1st – Olivia E. Todd, Colorado State University, *"Candidate Mutations for Fluroxypyr Resistance in Kochia from Colorado*".

Finally, a huge thank you to all the judges who contributed their time and energy for this year's contests.

Submitted by Carl Coburn – Chair
Student Paper Judging Committee

WSWS 2020 ANNUAL MEETING NECROLOGY REPORT

At the Thursday breakfast business meeting, the biographies of WSWS members who passed away this year were read, and a moment of silence was observed. Those members were:

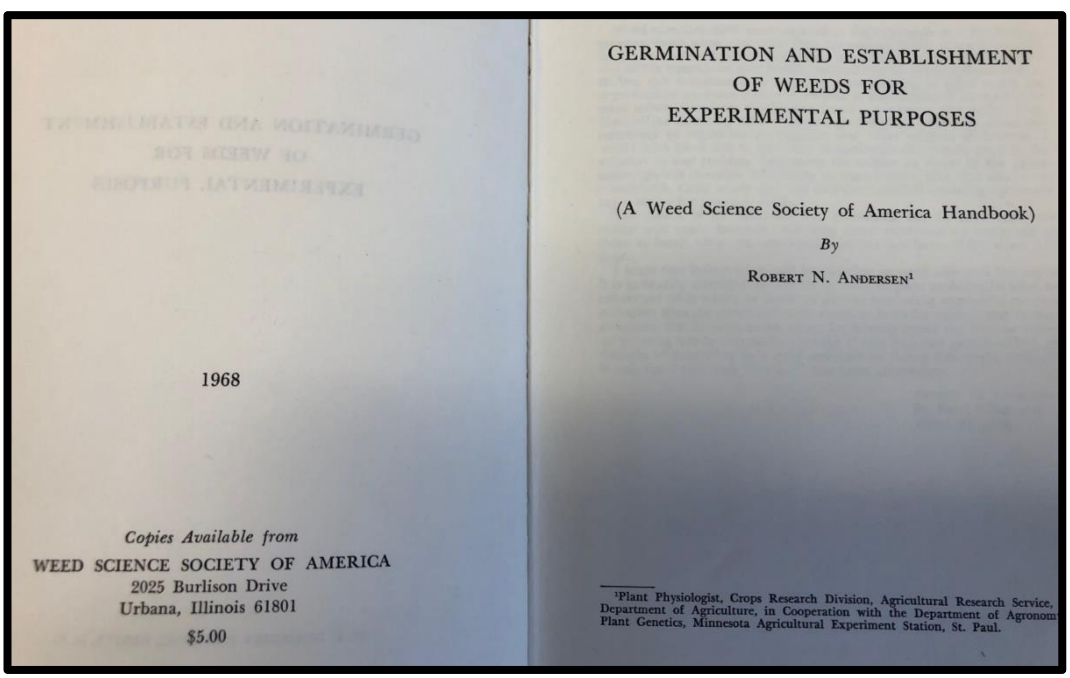
Jerry D. Caulder, November 7, 1942 - November 14, 2019, Rancho Santa Fe, California

Dr. Jerry Caulder died November 14th surrounded by family and friends from complications stemming from a long and arduous fight against cancer. Earlier in life he was an active contributor to the WSSA and regional societies. Born the son of a sharecropper in Gideon, MO to Charley and Bernice Caulder, he grew up in a loving home that valued education, leading him to eventually earn a PhD from the University of Missouri. He joined Monsanto Company in 1969 as a field scientist and rose to Director of Corporate Business Development. In 1984, he relocated to San Diego and became Chairman and CEO of Mycogen Corporation, an agricultural biotechnology company focused on pest control. After taking the company public and selling the company, he started other companies and later started a venture capital company for emerging technologies and creating future executive talent. He was a sought speaker and served on many congressional and “think tank” organizations. Of special note by many at his memorial was his generosity as well as quick wit.

Dr. Robert Neils "Bob" Andersen (1928 – 2019)

On Monday December 9th, 2019 Robert “Bob” N. Andersen, recently of Brainerd, MN, long time resident of Maplewood MN, passed away at the age of 91 due to complications from Parkinson’s Disease. Bob was born the youngest of three siblings on June 8, 1928 in Steele City, Nebraska, to Effie and Hans Christian Andersen. They knew the riches of family and the sweat and toil of getting by enduring the Great Depression. At seventeen Bob joined the army, serving in the Occupation of Korea between World War II and before the Korean War. Utilizing the GI Bill, he attended the University of Nebraska and received a Bachelor of Science in agronomy and continued on to earn his Master of Science. Later, he received a PhD from the University of Minnesota. His professional career was devoted to weed research for the U.S. Department of Agriculture, mostly at the University of Minnesota St. Paul campus. His book the "*Propagation and Establishment of Weeds for Experimental Purposes*", is still relevant in his field of research. Though he was known for his editorial red pen by his graduate students, they still lined up to have him as their advisor. A humorist and popular Master of Ceremonies, Bob shared his dry Mark Twain-like wit with many an audience. For over a decade his work in weed research had him collaborating and traveling to India. He assisted in the development of the Indian Weed Science Society. He learned Hindi out of love and respect for the Indian people.

One bit of advice Bob would leave with you, as attributed to Mark Twain: “Humor is Mankind’s greatest blessing”.



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GERMINATION AND ESTABLISHMENT
OF WEEDS FOR
EXPERIMENTAL PURPOSES

(A Weed Science Society of America Handbook)

By

ROBERT N. ANDERSEN[1]

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WSWS 2020 ANNUAL MEETING RETIREES REPORT

Since the last meeting, a total of five members of the society were brought forward as new or soon to be retired from the Western Society of Weed Science. The first four members were in attendance of our Maui meeting, and thus were formally recognized at the Business Meeting Breakfast. Their attendance, years of service, and professional leadership will be greatly missed.

Bill McCloskey, University of Arizona

Cheryl Wilen, University of California Cooperative Extension

John Roncoroni, University of California Cooperative Extension

Dallas Peterson, Kansas State University

Roger Hybner, Montana State University

Submitted by Andrew Kniss, Immediate Past President

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