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2014

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OF

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PREFACE

The Proceedings contain the written abstracts of the papers and posters presented at the 2013 Western Society of Weed Science Annual Meeting plus summaries of the research discussion sections for each Project. The number located in parenthesis at the end of each abstract title corresponds to the paper/poster number in the WSWS Meeting Program. Authors and keywords are indexed separately. Index entries are published as received from the authors with minor formatting 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: Bill McCloskey, University of Arizona

POSTER SESSION

Project 1. Weeds of Range and Natural Areas

Rosarubiginosa Encroachment on Conservation Reserve Program Grasslands. Hannah A. Tomlinson*[1], Timothy Prather[2]; [1]Student, Moscow, ID, [2]University of Idaho, Moscow, ID (001)

Sweetbriar rose (*Rosa rubiginosa; syn. Rosa eglanteria*) invades grassland systems, including Conservation Research Program grasslands within the Inland Pacific Northwest forming dense thickets that limit access and change plant diversity. The purpose of this study is to measure changes to plant diversity and to evaluate herbicide efficacy and herbicide application method efficacy. An experiment was established near Moscow ID to evaluate changes to plant communities with invasion from *R. rubiginosa* and to test efficacy of three herbicides with five different application methods. A total of 72 rose shrubs were chosen for this study; shrubs were divided evenly between blocks (i.e. 24 shrubs per block: 12 for each size class). Canopy and basal cover were visually measured using a 0.50cm—0.50cm quadrat, systematically placed at 1-m increments on three 20-m transects within three 20-m—20-m areas. *Rosa rubiginosa* density was also counted in each of the 20-m—20-m areas. Foliar applications took place in the fall (triclopyr, metsulfuron methyl, and imazapyr), and the basal bark (triclopyr) application in the winter (2014). The cut-stem application will take place in the spring of 2014 when the shrub is actively growing. Nine plant species were present on the site, three dominate the site as measured by % cover and included *Thinopyrum intermedium* (17.4 % ± 17.4%), *Rosa rubiginosa* (10.70 % ± 17%), and *Ventenata dubia* 18.20 ±15.48. Foliar treatments were evaluated November 14, 2013 for signs of herbicide symptomology. In all cases, triclopyr treated shrubs retained their leaves whereas; imazapyr and metsulfuron treated shrubs did not retain their leaves after frost. Regrowth of stems will be assessed in the spring of 2014.

Use of Herbicides for Control of Western Juniper in Early Stages of Sagebrush Community Encroachment. Sasha Twelker*[1], Gustavo M. Sbatella[2]; [1]Oregon State University, Madras, OR, [2]Oregon State, Madras, OR (002)

The objective of this study is to determine if herbicides can provide an effective way to control Western juniper in the early stages of encroachment. Two field studies are being conducted near Prineville, Oregon. In the first study, picloram, fluroxypyr, aminocyclopyrachlor, metsulfuron, triclopyr, imazapyr and glyphosate were tested with a foliar coverage application. Evaluations 120 days after treatment (DAT), showed that picloram (98%), picloram + fluroxypyr (98%) and glyphosate + imazapyr (93%) were the treatments that produced the highest percent of juniper damage. Lower levels of damage were observed when aminocyclopyrachlor was combined with metsulfuron (78%) or with triclopyr (86%). In the second study, picloram, hexazinone, aminocyclopyrachlor and triclopyr were tested with spot and basal bark as application methods. The highest level of tree damage was recorded with picloram when applied either as spot treatment (90%) or as basal bark (98%). Tree damage with spot application of hexazinone was 67% and 70%

for aminocyclopyrachlor plus triclopyr when applied as a basal bark treatment. While the levels of damage were significant, further evaluations are planned for next year that will provide more definitive conclusions regarding treatment.

Aminocyclopyrachlor Efficacy on Yellow Toadflax Varied by Growth Stage. Jason W. Adams*[1], Rodney G. Lym[2]; [1]North Dakota State University, FARGO, ND, [2]North Dakota State University, Fargo, ND (003)

Yellow toadflax control using aminocyclopyrachlor has been inconsistent and has ranged from 30 to nearly 100% 1 yr after treatment (YAT). Efficacy of aminocyclopyrachlor has also varied with yellow toadflax growth stage at application. The purpose of this research was to evaluate yellow toadflax control using aminocyclopyrachlor applied at four growth stages. Treatments included aminocyclopyrachlor at 70, 105, or 140 g ha^{-1} and the standard picloram plus dicamba plus diflufenzopyr at 1120 + 210 + 84 g ha^{-1} in June, July, August, or September 2012. Treatments were arranged in a randomized complete block design as a 4 by 4 factorial with four replicates. Yellow toadflax density was evaluated by counting the number of stems in four 0.5 by 0.5 m quadrats per plot before treatment and approximately 1 yr after treatment. Yellow toadflax control with aminocyclopyrachlor varied by growth stage. Control averaged 98% 1 YAT when aminocyclopyrachlor was applied in June but only 50% when the herbicide was applied in September. Yellow toadflax control with picloram plus dicamba plus difluefenzopyr averaged 92% 1 YAT and was not affected by application date. The current recommendation of treating yellow toadflax with aminocyclopyrachlor from midsummer to fall should be reconsidered.

Using Germination Differences to Remove Downy Brome from Reclamation Seed. William C. Rose*, Brian A. Mealor, Andrew R. Kniss; University of Wyoming, Laramie, WY (004)

Oil and gas extraction and surface mining create increased opportunity for infestation of new areas by weeds such as downy brome. Reclamation is implemented in an effort to restore native vegetation. However, downy brome often contaminates seed used for reclamation. Because downy brome germinates more rapidly and at colder temperatures than native grasses, it may be possible to remove downy brome using germination differences. During a 20 day germination treatment, four replicates of 50 seeds each of downy brome, bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Love), western wheatgrass, and blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths) were placed on filter paper in 9 cm^2 containers and assigned randomly to three germination chambers set at 3°C, 6°C, and 12°C. Following initial treatment, seeds were air-dried for 14 days on the laboratory bench. Containers were then reinserted into one of four chambers set at temperatures reported in the literature to be optimal for germination of each species. Four replicates of 50 untreated seeds for each species were also included. ANOVA revealed a significant temperature by species interaction ($p < 0.0001$). Downy brome displayed earlier and more rapid germination in all three temperatures. No downy brome survived the 6°C and 12°C treatments. However, untreated seeds achieved greater germination than the treated seeds among all species except blue grama. The 3°C treatment had no effect on germinability of blue grama seeds. Log-logistic regression revealed a margin of up to 1.5 days between 95% downy brome germination and 5% native grass germination.

Evaluating Multi-Species Targeted Grazing for Downy Brome Control. Cara E. Noseworthy*, Brian A. Mealor; University of Wyoming, Laramie, WY (005)

Downy brome (*Bromus tectorum* L.) is a damaging invasive plant widespread across rangelands in western North America. Although a good early spring forage, it is considered unreliable. Herbicides are commonly used to control downy brome, but targeted grazing could provide an alternative option for land managers. Targeted grazing may provide an economically feasible control method by allowing ranchers to use their livestock rather than incurring the added expense of herbicides. Few studies have directly compared herbicides and targeted grazing for downy brome control. This study's objectives are to: determine the effectiveness of targeted grazing for downy brome control, determine the effects of livestock species and timing on downy brome populations, and compare the results to those of commonly used herbicide treatments. Plots are located in Lingle, Wyoming and arranged in a randomized complete block design with three replicates of twelve treatments. Grazing treatments included cattle, sheep, and both species in the spring, fall, and both spring and fall at a stocking density of approximately 247 au ha^{-1}. They were applied in spring and fall of 2013. Herbicide treatments included imazapic at 123 g ai ha^{-1} and rimsulfuron at 52.5 g ai ha^{-1} applied early post-emergent in fall 2013. Canopy cover data (Daubenmire) were collected pre and post treatment, and analyzed using a one way ANOVA. Both herbicides and spring + fall sheep grazing reduced downy brome cover within the season of application. Future efforts include collecting biomass and seed production data to gain insight into effects on downy brome reproduction.

Herbicide Effects On Soil Microbiota As Determined By Phospholipid Fatty Acid Analysis. Beth Fowers*[1], Brian A. Mealor[1], Caley Gasch[2]; [1]University of Wyoming, Laramie, WY, [2]Washington State University, Pullman, WA (006)

Reclamation efforts are aimed at restoring ecosystem structure and function through reestablishment of desirable vegetation. Many restoration efforts focus only on monitoring vegetation response, although soil microbial communities can affect an ecosystem and may be an important factor when considering recovery. Response of soil microbial communities to herbicides is not well documented. A study on reclamation options including seeding desirable species and herbicide application to control weeds was conducted. Our objective was to evaluate the effects of various herbicides and the resulting plant cover on soil microbiota in a reclamation setting. Soil samples (top 10 cm) were collected from each herbicide treatment at one field site in mid-August 2012 after late summer precipitation, following a dry spring and summer. Samples were analyzed using a modified Bligh-Dyer methodology of phospholipid fatty acid analysis which gives an estimate of relative abundance after which microbial signatures were grouped into functional types. Herbicides had no effect on microbial communities. Regressions showed significant positive relationships between annual forb cover and both saprotrophic fungi (p=0.0153) and protozoa communities (p=0.0272). However, increases in microbial abundances of those groups were very small, roughly 0.1 ug fatty acid per g soil difference. Regression of perennial grass and microbial population showed no relationship (p>0.05). However, AM fungi regressed on perennial grass indicated a slight positive biological association. Microbial activity is greatest when moisture levels are higher, so it is possible that some herbicide and microbial effects were not observable because of the late season sampling.

How Changes in Soil Nitrogen and Available Water Holding Capacity Affect Establishment of Hydro-seeded and Invasive Species in Rocky Mountain National Park. Lindsay N. Ringer*; Colorado State University, Fort Collins, CO (007)

We propose that soil amendments which improve water and nutrient cycling properties can change competition between native and invasive species. Combinations of yard-waste compost, super absorbent polymer, and wood mulch have the potential to alter soil characteristics closely tied to plant growth. Compost provides slowly-available nitrogen through organic matter, polymers improve the ability of soils to hold water at the surface for germination, and wood mulch can balance temperature fluctuations. We will target south-facing slopes along Bear Lake Road in Rocky Mountain National Park to monitor germination of species in their most water-stressed environments. Fieldwork will be paired with greenhouse studies to examine competition under varying soil conditions. Hydro-seeded species in the study are*Elymus elymoides* and *Elymus canadensis.* Site specific, invasive species are *Bromus tectorum* and *Bromus inermis*. This research seeks to proactively discourage invasion and encourage establishment of seeded species through the management of soils.

Effects of Defoliation on Dalmatian Toadflax and Four Native Grasses. Julia M. Workman*, Brian A. Mealor; University of Wyoming, Laramie, WY (008)

The noxious perennial forb Dalmatian toadflax (*Linaria dalmatica* [L.] Mill.) is problematic in western North America because of its ability to outcompete native communities. Targeted grazing, which involves manipulation of defoliation timing, intensity, frequency, and herbivore species to achieve the desired effect on weed and desirable species, may be a successful control technique but has not been investigated in-depth for this plant. We sought to evaluate how grazing patterns with varying intensity and selectivity would affect toadflax and grass interactions. Dalmatian toadflax individuals were grown in pots with and without native grass neighbors. We applied defoliation to the four grasses at one of three levels (check, moderate, or high) and to the toadflax at one of four levels (check, moderate, high, or stripped). Total aboveground biomass and percent change in height and stem number were analyzed for each plant at the end of the study using a three-factor factorial ANOVA. Defoliation decreased total grass biomass ($p < 0.0001$). Regrowth following defoliation differed among grass species ($p < 0.03$). Toadflax plants whose leaves had been stripped had the lowest total biomass and regrowth. When competitive grasses are present in the community, grazing by a selective feeder with a preference for toadflax may be a successful Dalmatian toadflax management strategy. Conclusions are limited because this study was conducted in a greenhouse using simulated grazing, but a follow-up field experiment will be initiated in spring 2014.

African Rue Control on Colorado Native Rangeland. James R. Sebastian*[1], George Beck[2]; Scott J. Nissen. [1]CSU, Loveland, CO, [2]Colorado State University, Fort Collins, CO (009)

African rue (*Peganum harmala,* PEGHA) is an invasive, succulent, perennial herb with a bushy growth habit that reaches about 1 ft in height at maturity. In Colorado, PEGHA initiates new growth in early spring and senesces as soils dry in early summer. PEGHA has a deep, woody root system that is a major obstacle for long-term control. Herbicides were applied at three timings; when PEGHA was in the bud growth stage, flowering, or in fall. Tebuthiuron (Spike 80W at 3% w/v), imazapyr (Arsenal at 3% v/v), or hexazinone (Velpar L at 50% v/v). All broadcast treatments were applied with a CO_2-pressurized backpack sprayer using 11002LP flat fan nozzles at 20 gal/A and 30 psi. Spot treatments were sprayed at the flower and fall timings. Individual plants were spot treated at 30 psi with a Spray Systems spray handgun with 4003E tips. All imazapyr treatments sprayed on May 26, 2010 when PEGHA was at bud growth stage provided 100% control approximately 15 months after treatment (MAT). Imazapyr spot or broadcast sprayed on June 8, 2010 at the flower growth stage provided 93 to 100% PEGHA control 15 MAT. All fall-applied treatments failed possibly due to the extreme drought conditions. All tebuthiuron and hexazinone treatments provided 4 to 55% PEGHA control. Hexazinone turned PEGHA plants yellow in 2010 and 2011. Imazapyr or imazapyr tank-mixes are very active on the root system and have consistently provided the best PEGHA control when sprayed during optimal weather conditions. Spraying PEGHA in droughty years with poor vegetative growth has resulted in poor control. Imazapyr often injures non-target plants including perennial grasses. Spot spraying individual PEGHA plants with imazapyr may provide the greatest selectivity in a plant community.

Efficacy of Herbicide Ballistics Technology for the Control of Salt Cedar and Russian Olive in Fremont County, WY. John L. Baker*[1], Michael Wille[2], James Leary[3]; [1]Fremont County Weed and Pest, Lander, WY, [2]Fremont County Weed and Pest, Riverton, WY, [3]University of Hawaii at Manoa, Kula, HI (010)

A study was established to evaluate the usefulness of Herbicide Ballistics Technology for the control of Salt cedar and Russian olive by selecting one hundred plants of each species along Five Mile Creek, a tributary to Boysen Reservoir 20 miles north of Riverton, WY. Each plant was photographed, evaluated for height, width and number of stems, and identified with numbered tags. Treatments and checks were assigned randomly. Standard foliar, cut stump and basal bark treatmets were compared to Herbicide Ballistics Technology, HBT, a pesticide application technique developed by Dr. James Leary, University of Hawaii, where a standard 2 milliliter paint ball was loaded with oil and herbicide mixtures of Triclopyr and Imazapyr and fired with compressed air at the target plants from a distance. The herbicide is released on impact. Doses of 6, 12, 18 and 24 herbicide loaded balls were were applied to one side of the plants 12 to 15 inches from the ground. Plants were evaluated at 12 and 24 months after treatment. A dose responce curve for Triclopyr and oil was established for Salt cedar that could be used to fine tune the application methods and rates to get results comparable with currently labeled basal bark and cut stump applications while using significantly reduced amounts of active ingredient. Imazapyr treatments were less consistent on both species and resulted on non-target injury to nearby plants. Potential certainly exists to use HBT with the Triclopyr and oil mixture for Salt cedar control on scattered populations in rough country. On Russian olive the results were inconsistent with both herbicides at the tested application rates. Russian olive control was generally poor suggesting that HBT would have limited application for the control of that species.

High Temperature and Moisture Effects on the Germination of Dyer's Woad Seeds. James J. Stapleton[1], Steve B. Orloff*[2], Nicole O. Luiz[2]; [1]University of California, Parlier, CA, [2]University of California, Yreka, CA (011)

Dyer's wood (*Isatis tinctoria*) is a problematic, invasive weed in the intermountain west, including far northern California. Although it can be controlled by properly-timed herbicide applications prior to seed set, it continues to spread at an alarming rate along roadsides, fencerows, and ditchbanks, as well as on rangeland and natural areas. Observational germination assays during 2013 showed that a portion of seeds became germinable only a few days after anthesis, so effective herbicide or mechanical control measures cannot be delayed in the springtime. Additional studies were initiated to estimate the feasibility of using solar tents (1, 2), a hydrothermal method of inactivating seeds. This safe, easy, and inexpensive method may be useful to halt spread of small stands of Dyer's woad and other weeds. Moistened seeds, enclosed within silicles, were susceptible to effects of high temperature. Preliminary data showed seed germination to be completely inhibited by 20 min exposure to 70 C; 75 min to 60 C; and 28 hr to 50 C. The silicle covering provided protection to seeds against heat exposure, especially at the lower temperatures tested. Preliminary field experiments to test effects of seed incubation in solar tents suggested that germination was greatly reduced during summer months in the Scott Valley, Siskiyou County, California, when seed lots were immersed in water, but not when they were only exposed to water vapor. References: (1) Orloff, S.B. 2008. Website *http://cesiskiyou.ucanr.edu/newsletters/Spring_200839564.pdf*, (2) Stapleton, J.J. 2009. Website *http://www.cal-ipc.org/symposia/archive/pdf/2009/5Stapleton.pdf*, and (3) Stapleton, J.J. 2012. *Journal of PestScience* 85:12-17

NetMaps, Creating a Spatial Information Cloud to Facilitate Invasive Plant Susceptibility Modeling. Larry W. Lass*, Timothy Prather; University of Idaho, Moscow, ID (012)

Land managers and researchers working with invasive species are often hampered in their efforts by an inability to access shared spatial data and use it as a real time planning tool. Recent technological breakthroughs in cloud computing and wireless data syncing may make spatial data sharing between agencies and entities possible and economical for evaluating mapping priorities and susceptible areas. Netmaps polygon data entry and display servers are designed for multiusers with many different devices. Data may be used on Android and Iphone/Ipad based using the Collector or Arcgis apps as mobile platforms or a web browser using the Arconline java app or with Arc Desktop 10 for computers in the office. Portal is available at http://uidaho.maps.arcgis.com and select *Invasive Plant Training* for fully functional training data. Collector is an out of box ready to use app allowing both online and soon offline functionality. Once users become trained they will need to sign up to arcgis.com (free) and access the *Invasive Plant Public Mapping* to allow user tracking and mapping. The Invasive Plant Public Mapping attributes are species, cover, community type, phenology, disturbance, and date and do not show ownership data although the user may link ownership through an outside website. Users will find site susceptibility maps for 24 weed species currently being mapped by Idaho and Montana land managers a useful background map when searching for new infestations. The site susceptibility maps are based on current Netmap data where models used a distance algorithm to match vegetation (satellite NDVI), maximum and minimum temperature, and potential sun radiation of training data to predict the site's susceptibility to invasion. Netmap is one small step to enhanced invasive plant mapping where ever you stand on earth.

Photoperiod Effects on Growth and Development in Yellow Starthistle. David Bubenheim*[1], David Spencer[2], Ivy Liow[2]; [1]NASA - Ames Research Center, Moffett Field, CA, [2]USDA-ARS Exotic & Invasive Weeds Research Unit, Davis, CA (138)

Yellow Starthistle (*Centaurea solstitialis*) is a native annual weed of Eurasia and since introduction into the US has become an invasive and noxious weed. It grows in a rosette habit during the vegetative state and usually bolts in summer to produce a large and branched flowering stem. Time to flowering in Yellow Starthistle has been attributed to photoperiod, nitrogen nutrition, temperature, and water stress. We executed a series of studies to investigate the role of light, both photoperiod and photosynthetic photon flux, on flowering and development in Yellow Starthistle. Treatments were presented in 3 ways: 1) varying day length with constant photosynthetic photon flus (PPF) – providing increasing daily integrated Photosynthetic Photon (PP) exposure with longer day lengths, 2) varying day length while adjusting PPF to maintain daily PP exposure for all treatments and, 3) extending photoperiod treatments beyond common 12-h photosynthetic period with low light levels to maintain both PPF and daily PP across all treatments.

Yellow Starthistle appears to be a long-day plant with a critical day length requirement between 14-h and 16-h to induce transition from vegetative to floral stages in development. PPF and daily absorbed photons did not affect time to vegetative / floral stage transition, but did affect factors such as biomass accumulation and canopy parameters such as specific leaf mass.

Project 2. Weeds of Horticultural Crops

Postemergence Control of Glyphosate-Paraquat Resistant Hairy Fleabane (*Conyza bonariensis*) in Orchards of California. Marcelo L. Moretti*[1], Kurt J. Hembree[2], Anil Shrestha[3], Bradley D. Hanson[1]; [1]University of California, Davis, CA, [2]Cooperative Extension Fresno County, Fresno, CA, [3]California State Fresno, Fresno, CA (013)

Hairy fleabane is an important weed in tree nut orchards of California. Weed control in these crops relies on the use of herbicides, including POST herbicides for pre-harvest weed control. Among the herbicides most used in tree nut crops are glyphosate and paraquat. Recently, hairy fleabane populations resistant to glyphosate and paraquat were documented in the state, and together with the already wide-spread glyphosate-resistant (GR) populations they can interfere with effective orchard weed management. Information on management of GR and glyphosate-paraquat-resistant (GPR) populations with other herbicides is needed. The objective of this study was to evaluate efficacy of several POST herbicides on GPR and GR hairy fleabane. Three field experiments were conducted in commercial almond orchards during summer (June-August) 2012 and 2013 in Merced County, CA. The 2012 trials were conducted in locations known to be infested with GR hairy fleabane. The 2013 trial was conducted in an orchard suspected to be resistant to both glyphosate and paraquat. Treatments were applied when hairy fleabane was at the bolting or reproductive stage and included carfentrazone, glyphosate, glufosinate, paraquat, saflufenacil, and

2,4-D, applied alone or in mixtures, as well a sequential application of glyphosate followed by paraquat 14 days later. Glyphosate or carfentrazone applied alone or in mixture did not control hairy fleabane at any of the locations. Paraquat, either alone or as a sequential application of glyphosate followed by paraquat was effective in controlling GR populations in 2012, but did not provide control of the GPR plants in 2013. Glufosinate or saflufenacil provided more than 80% control of both GR and GPR hairy fleabane in both years. Glyphosate plus 2,4-D provided inconsistent control, inconsistence that may be a result of difference in plant size because smaller plants were better controlled with glyphosate plus 2,4-D than larger ones. Of the currently registered POST herbicides, glufosinate and saflufenacil can effectively control GPR and GR hairy fleabane in California tree nut orchards.

Effects of Plow-down and Cover Crops for Tulip Production in Western Washington. Yushan Duan*[1], Carl R. Libbey[2], Gary A. Chastagner[3], Ian C. Burke[4], Ann C. Kennedy[5], Michael A. Jacroux[6], Timothy W. Miller[7]; [1]Grad Student, Pullman, WA, [2]Research Tchnologist, Mount Vernon, WA, [3]Plant Pathologist, Puyallup, WA, [4]Washington State University, Pullman, WA, [5]USDA Soil Scientist, Pullman, WA,[6]Professor, Pullman, WA, [7]Research and Extension Scientist, Mount Vernon, WA (014)

Tulip is grown on over 400 acres in western Washington, representing 76% of U.S. tulip production. It is a poor weed competitor and susceptible to soilborne diseases due to shallow roots and long growing season. Growers currently rely primarily on pesticides for weed and disease management. However, pesticide applications are sometimes limited by proximity to sensitive areas and products are sometimes inadequate. To better control weeds and diseases in tulip as well as potentially reducing pesticide reliance, green manures and cover crops consisting of cereal rye, green pea, or mustard were tested in western Washington. Green manures combined with or without glyphosate application prior to incorporation were tested in a large-scale field trial. In the two summers of this trial, weed growth before cover crop termination was not affected by cover crops. Flower quality and bulb yield from the single year of tulip production thus far did not differ among cover crop treatments. In a small-scale field trial, cover crops were seeded in early July or early August, treated with glyphosate, and either incorporated or left on the soil surface prior to tulip bulb transplanting. In the first year of that trial, total biomass of early seeded cover crops was 66% greater than late seeded crops. Mustard produced 34% more biomass than a cereal rye and pea mix when seeded in early July. Weed growth before cover crop termination was reduced up to 100% and 97% by cover crops in small-scale field and greenhouse trials, respectively, regardless of cover crop species and seeding dates

Biofumigation for Weed Management in Cabbage. Mustapha A. Haidar*; American University of Beirut, Beirut, Lebanon (015)

Field studies were conducted in Lebanon to investigate the effect of solarization with/without cover crop green manure on weed population in subsequent planting of cabbage. Cover crops (alfalfa, barley, clover, lathrus and vetch) or crushed olive pulp were planted/added in 18 m^2 plots 75 days prior to planting cabbage. Crops and crushed olive pulps were ploughed under (CCGM) and then half the plots in each treatment were solarized (Biofumigation) by covering each plot with a clear polyethylene sheet for 40 days. Solarization with or without biofumigation significantly reduced weed population in subsequent cabbage planting as compared to nonsolarized CCGM or to the control. Solarization and biofumigation significantly increased fresh weight of cabbage as compared to the control and to nonsolarized CCGM treatments. Optimal weed control was observed in plots that were biofumigated with clover as a CCGM.

Herbicide Combinations for White and Red Fresh-Market Potatoes Grown in Western Washington. Carl R. Libbey*[1], Timothy W. Miller[2]; [1]Washington State University, Mount Vernon, WA, [2]Research and Extension Scientist, Mount Vernon, WA (016)

Herbicide combinations were evaluated for weed control and phytotoxicity in fresh-market potatoes at Mount Vernon, Washington in 2010 through 2013. Single-drop seed potatoes were planted in June 2010 (cv. 'White Rose' and 'Chieftain'), May 2012 (cv. 'Cal White' and 'Chieftain'), and May 2013 (cv. 'Chieftain'). Preemergence herbicides were applied after hilling (June 23, 2010, June 11, 2012, and June 8, 2013) and postemergence herbicides were applied 3 weeks after hilling (July 16, 2010). Herbicides tested alone or in combination were rimsulfuron (Solida and Matrix), s-metolachor + metribuzin (Boundary), fomesafen (Reflex), s-metolachor (Dual Magnum), and pendimethalin (Prowl H_20). Weed control and visual crop injury were evaluated through the growing season. At the end of the season, tubers from three plants were harvested, counted, and weighed. Primary weed species in all three trials included common lambsquarters, ladysthumb, pale smartweed, and shepherd's-purse. No treatment caused visible crop injury at any point during any of the three trials. Total tuber weight and tuber number were not reduced compared to non-treated potatoes and the calculated average tuber weight was also statistically similar across all treatments. Early season weed control exceeded 90% for all treatments during all three growing seasons. Late season weed control differed by year. In 2010, control was diminished but was still >90% among all rimsulfuron treatments. In 2012 rimsulfuron alone or in combination with other products resulted in >90% weed control in the latter part of the growing season. S-metolachlor + fomesafen gave reasonably good control although slightly lower than rimsulfuron or rimsulfuron + tank mix partner treatments. Fomesafen and rimsulfuron alone exceeded 78% weed control in 2013. Combining s-metolachlor and rimsulfuron with fomesafen improved overall weed control. None of the tested herbicides resulted in adequate control of ladysthumb and pale smartweed. Maximal weed control in potato grown in northwestern Washington may therefore require additional herbicide combinations or sequences where these species occur.

Field Bindweed Control in Early- and Late-Planted Processing Tomatoes. Lynn M. Sosnoskie*[1], Bradley D. Hanson[2], W. Thomas Lanini[1]; [1]University of California - Davis, Davis, CA, [2]University of California, Davis, CA (017)

Processing tomato production in California has changed, dramatically, over time. Breeding efforts, the switch from seeds to transplants, the commercialization of the mechanical harvester, and the steady adoption of drip irrigation have helped to expand the total area planted to tomatoes (>250,000 acres in 2012) and increase yields (>45 tons/A). The use of drip-irrigation has also facilitated the adoption of minimum tillage in processing tomato (to maximize the lifespan of the irrigation infrastructure), which, in turn, has created a system where field bindweed (*Convolvulus arvensis*) has become more prevalent. Although bindweed seedlings can be readily managed via chemical and cultural means, perennial plants with extensive root systems are less susceptible to control measures.

Tomato growers in California have some flexibility with respect to the timing of crop planting so as to fulfill pre-contracted production requirements. Producers engaged in IPM practices may also wish to manipulate planting dates to take advantage of differential weed species germination and emergence; for example, growers may choose to plant early, to avoid barnyardgrass, or late, to avoid dodder. It is unknown if a similar strategy could be employed to help with the management of field bindweed. The objective of this study was to evaluate field bindweed control in early and late planted processing tomato**.**

The two timing treatments (early and late) were selected to simulate potential planting dates available to growers to meet season-long processing needs. The early planting was established on 11 April, 2013 (variety AB2); the late planting was established on 4 June (variety BOS3155). Transplants were set using sprinklers. The herbicide programs evaluated in this study were a combination of pre-plant (PP) (glyphosate - Roundup Powermax at 56 oz/A), pre-plant incorporated or pre-emergence (PPI/PRE) (trifluralin - Treflan at 32 oz/A alone or in combination with rimsulfuron - Matrix at 2 oz/A, metolachlor - Dual Magnum at 27 oz/A, or sulfentrazone - Zeus at 3.2 oz/A) and post-emergence or shielded (POST/SHIELD) (rimsulfuron - Matrix at 2 oz/A, carfentrazone - Shark at 2 oz/A) products. Each unique treatment combination was replicated three times per planting date. Check plots were also included for comparison. Crop injury and bindweed cover/density were evaluated weekly. The crop was harvested at maturity.

Bindweed pressure varied between planting dates. No emerged bindweed was observed in April; therefore, the PP burndown was not included in this portion of the study. The use of glyphosate as a PP burndown in late-planted processing tomatoes (up to 95% bindweed cover 2-3 weeks prior to transplanting) improved bindweed control across all treatments. For example, bindweed cover 2-6 WAT in the PPI trifluralin treatment ranged from 5-15%, when glyphosate was applied PP, as compared to 25-30% when it was not. Similar results were observed for trifluralin (PPI) + metolachlor (PPI) (7-9% vs 17-21%), trifluralin (PPI) + rimsulfuron (PRE) (6- 9% vs 15-27%) and trifluralin (PPI) + sulfentrazone (PPI) (7% vs 15-18%). In early planted tomatoes, bindweed cover was significantly reduced by the use of PPI/PRE herbicides prior to transplanting. Mean field bindweed cover in the check plots ranged from 6-27% (2-6 WAT), whereas mean weed cover in the PPI/PRE herbicide treated plots did not exceed 7% for any observation period. Field bindweed cover in late planted tomatoes was also significantly reduced, relative to the check, by the use of PPI/PRE herbicides. Bindweed cover in check plots ranged from 8-42% (2-8 WAT), whereas field bindweed cover in the PPI/PRE herbicide-treated plots never exceeded 24%. Although not all of the comparisons were statistically significant, the application of additional PPI/PRE chemistries (e.g. metolachlor, rimsulfuron and sulfentrazone) with trifluralin helped reduce field bindweed numbers in late planted tomatoes for up to 3 WAT.

Crop injury was observed in all herbicide treated plots for both planting dates. Symptoms ranged from stunting (sulfentrazone PPI) to chlorosis (rimsulfuron POST) to necrosis (carfentrazone SHIELD), although ratings did not exceed 20% for any treatment. The use of trifluralin alone (178 lbs/30 ft row) or in combination with metolachlor (173 lbs/30 ft row), rimsulfuron (162 lbs/30 ft row) or sulfentrazone (178 lbs/30 ft row) improved crop yields, significantly relative to the untreated control (175 lbs/30 ft row) in early-planted tomatoes. Similar results were observed with the late-planted crop; the use of trifluralin alone (327 lbs/30 ft row) or in combination with metolachlor (362 lbs/30 ft row), rimsulfuron (373 lbs/30 ft row) or sulfentrazone (339 lbs/30 ft row) improved crop yields, significantly relative to the untreated control (283lbs/30 ft row). Rimsulfuron (POST) and carfentrazone (SHIELD) improved tomato yields by 20 to >40 lbs per 30 feet of row (Data not shown).

Results from this trial are in agreement with previously conducted studies that field bindweed in processing tomatoes can be suppressed, but not controlled by herbicides. However, the outcomes observed in this study also suggest that herbicide combinations (PP, PPI/PRE and POST/SHIELD) could be more beneficial to growers than the use of a single product, depending on the status of fieldweed at the time of transplanting. In order to maximize yield, tomatoes must remain relatively weed-free for up to two months after planting. Information regarding the performance of registered herbicides against field bindweed - as they are affected by the timing of crop planting and weed management practices - will help growers to better direct their production efforts so as to minimize weed interference, increase crop yield and increase profits. Future studies will be designed to: Compare the effects of subsurface drip and furrow irrigation on weed control by trifluralin, metolachlor, rimsulfuron and sulfentrazone applied alone or in combination; evaluate trifluralin used as a layby treatment for season-long bindweed management; compare the efficacy of sequential applications of rimsulfuron (POST) or rimsulfuron (POST) followed by carfentrazone (SHIELD) for the management of field bindweed; determine how the control of field bindweed by trifluralin and other herbicides is affected by rhizome size and burial depth.

Project 3. Weeds of Agronomic Crops

A New Website and Smartphone App for Quick Reference of Spray Quality for Ground Applications. Ryan S. Henry*[1], Cody F. Creech[1], Lowell Sandell[2], Greg Kruger[3]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]University of Nebraska, Lincoln, NE (018)

Understanding droplet size from pesticide applications is critical for growers and professional applicators to make the best decision for maximizing pesticide efficacy while minimizing drift potential. The droplet size and spray quality of a pesticide application can be influenced by a variety of factors, including nozzle type, orifice size, operating pressure, and chemistries of the tank mixtures. Growers and pesticide applicators have numerous choices in regards to these factors, but it is difficult to obtain accurate and timely information on these factors' cumulative effect on the droplet size and spray spectrum. To aid growers and applicators in this regard, a custom iPhone and Android application (app) has been created and published. In addition, a website with similar functionality of the app including some additional features is in the late stages of development. These free tools will allow the user to quickly determine the droplet size and quality of an application with user-defined parameters. The app also allows the user to save and/or send the results to another party in real time. The data for these tools is generated using a low speed wind tunnel and laser diffraction system at the West Central Research and Extension Center in North Platte, NE. As the database for the app and website grows, it will further aid the end users across the US and the world to make an informed decision before making a pesticide application.

Influence of Carrier Volume on Droplet Spectra and Herbicide Efficacy. Cody F. Creech*[1], Ryan S. Henry[1], Lowell Sandell[2], Greg Kruger[3]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]University of Nebraska, Lincoln, NE (019)

Herbicide applicators have grown accustomed to low carrier volumes that are customary with glyphosate applications. These low carrier volumes are highly efficient for glyphosate applications and allow applicators the ability to treat a large amount of acres in a timely manner. However, the increasing use of herbicides other than glyphosate requires evaluating the impacts of carrier volume on weed control efficacy. The effects of six carrier volumes (47, 70, 94, 140, 187, and 280 L ha^{-1}) were evaluated with five herbicides in both field and greenhouse studies in 2012 and 2013. Glyphosate (0.87 kg ae ha^{-1}), glufosinate (0.59 kg ai ha^{-1}), lactofen (0.11 kg ai ha^{-1}), 2,4-D (0.20 kg ae ha^{-1}), and fluazifop-P (0.07 kg ai ha^{-1}) were applied at reduced rates with each carrier volume. In addition, recommended adjuvants were added to each tank mix at recommended rates. The droplet spectra for each herbicide and carrier volume combination was evaluated at the Pesticide Application Technology (PAT) Laboratory in North Platte, NE. Treatments were applied to five plant species at the PAT Lab, corn (*Zea mays*), shattercane (*Sorghum bicolor*), flax (*Linum usitatissimum*), velvetleaf (*Abutilon theophrasti*) and grain amaranth (*Amaranthus hypochondriacus*), using a single track sprayer. Fluazifop-P treatments were only applied to grass species and 2,4-D was only applied to broadleaf species. Treatments were applied when plants were approximately 10 and 32 cm in height. Visual estimations of injury were collected at 7, 14, and 28 days after treatment (DAT) using a scale of 0 – 100 where 0 = no injury and 100 = plant death. At 28 DAT, plants were clipped at the soil surface and wet weights were recorded. These samples were then dried and dry weights were recorded. In addition, treatments were applied at four field sites in Nebraska and visual injury ratings were recorded. Generally, herbicide performance increased as carrier volume increased. The contact herbicides glufosinate and lactofen responded more to the increase in carrier volume. Based on the data collected in these experiments, using carrier volumes on the higher end of the recommendations on the labels will provide the best weed control.

15 Years of Downy Brome Control in Eastern Washington. Nevin Lawrence*[1], Ian C. Burke[1], Joe Yenish[2]; [1]Washington State University, Pullman, WA, [2]Dow AgroSciences, Billings, MT (020)

Downy brome (*Bromus tectorum*) is an invasive winter annual grass species wide spread throughout western North America. As new herbicides, particularly the sulfonylureas, were introduced, downy brome control has transitioned to near total reliance on herbicides. The past 15 years of field trials for the control of downy brome in Washington include 27 studies conducted at five different sites in diverse precipitation zones. Visual estimates of weed control were analyzed for applications of diclofop, flucarbazone, imazamox, mesosulfuron, metribuzin, propoxycarbazone, pyroxsulam, and sulfosulfuron. Average control (S.E.) over the past 15 years for diclofop, flucarbazone, imazamox, mesosulfuron, metribuzin, propoxycarbazone, pyroxsulam, and sulfosulfuron used alone were 56 (5.7), 53 (10), 82 (6.4), 63 (9), 44 (9.8), 76 (5.3), 76 (5.3), and 72% (7.1), respectively. When ranking herbicides by year, imazamox provided the highest average control for four separate years (2001-2003 and 2006), propoxycarbazone provided the highest control for three separate years (2005, 2009, and 2011), and pyroxsulam provided the highest control for two separate years (2008 and 2012). Control differed substantially between fall and spring applications for propoxycarbazone (84 to 72%), pyroxsulam (88 to 72%), and sulsulfuron (83 vs 70%). Metribuzin was commonly used as tank mix partner with flucarbazone, imazamox, mesosulfuron, propoxycarbazon, and sulfosulfuron. However, metribuzin as a tank mix partner only improved average control when used with flucarbazone (91%) and mesosulfuron (82 %). When mesosulfuron was used as a tank mix partner with propoxycarbazone control was not improved. No differences in control between sites or precipitation zones were evident.

Molecular Characterization of Glyphosate- and Acetolactate Synthase Inhibitor-Resistant Kochia from Montana. Vipan Kumar*[1], Prashant Jha[1], Phil Westra[2], Eric P. Westra[2], Darci Giacomini[2], Christopher Vanhorn[2], Aruna Varanasi[1]; [1]Montana State University, Huntley, MT, [2]Colorado State University, Fort Collins, CO (021)

Occurrence of herbicide-resistant kochia is an increasing concern for growers in the Northern Great Plains. Based on whole-plant dose response assays, we found evolution of glyphosate-resistant (Gly-R) kochia biotypes (GIL01, JOP01, CHES01) in chemical-fallow wheat fields in Hill and Liberty Counties of Montana (resistance index of 4.5- to 11-folds). All Gly-R biotypes were resistant to the acetolactate synthase (ALS)-inhibitor herbicides (chlorsulfuron, metsulfuron, and thifensulfuron + tribenuron), but susceptible to dicamba and fluroxypyr. The objective of this research was to investigate the molecular mechanism(s) conferring resistance to glyphosate and ALS-inhibitor herbicides in kochia. For glyphosate resistance, 5-enolpyruvylshikimate-3-phosphate synthase (*EPSPS)* gene was analyzed for target-site mutations (PCR and sequencing), relative increase in gene copy numbers through qPCR, and protein accumulation (Western blot). Also, the Gly-R biotypes were characterized for the known mutations on a 2 kb fragment of *ALS* gene. No target-site mutations were detected at Pro_{106} of *EPSPS* gene. All Gly-R biotypes had increased *EPSPS* gene copies (~ 4 to 10) compared with a susceptible biotype (single*EPSPS* gene copy). Furthermore, Gly-R kochia plants accumulated higher *EPSPS* protein in western blot. Elevated levels of *EPSPS* protein in Gly-R plants correlated with increased *EPSPS* gene copy numbers. Resistance to ALS-inhibitor herbicides was conferred by Pro_{197} amino acid substitution (proline to glutamine). Based on this research, *EPSPS* gene amplification and a single target-site mutation at Pro_{197} confers resistance to glyphosate and ALS-inhibitor herbicides, respectively, in multiple herbicide-resistance (MHR) kochia biotypes from Montana. This is the first molecular confirmation of MHR kochia in Montana.

Kochia Resistance to Dicamba: Whole Plant Response vs. In Vitro Screening. David A. Brachtenbach*, Phil Stahlman; Kansas State University, Manhattan, KS (022)

Kochia (*Kochia scoparia*), has become highly problematic throughout the Great Plains of North America as a result of evolving resistance to multiple herbicide mechanisms of action. Commercialization of soybeans and cotton with tolerance to dicamba is anticipated in 2015, pending regulatory approval. Widespread adoption of this technology likely will increase dicamba use and selection pressure on weed populations. This research compared plant response of 34 kochia populations from western Kansas, the Oklahoma Panhandle, and central/eastern South Dakota to 460 g ha^{-1} of dicamba in a greenhouse when plants (10-12 per population) were 5-10 cm tall and evaluated an *in vitro* procedure for screening populations for resistance to dicamba. At 5 weeks after treatment the populations were categorized into groups of susceptible, moderately susceptible/tolerant and tolerant based on plant mortality and plant growth reduction (dry wt.) Three populations were selected from each category for screening using an *in vitro* procedure. Kochia seed was surface sterilized and cultured in Petri dishes (12 per dish) containing a sterilized medium of MS salts, vitamins, sucrose and 0, 0.5, 1, 5, 10, or 50 μM doses of dicamba. Cultures were maintained in a growth chamber at 24°C and 16/8-h day/night photoperiod. Germination was counted 1 WAT and plants with true leaves present were counted 2 WAT. The greenhouse experiment found wide differences among the populations in response to dicamba, from susceptible to moderately-resistant. The moderately-resistant populations produced true leaves in the *in vitro*experiment, whereas the susceptible populations did not; largely consistent with the whole plant testing results. Low to moderate-level of resistance to dicamba found in some kochia populations indicates the need for strong stewardship recommendations for dicamba use and diverse management practices to prevent further evolution of kochia resistance to dicamba. With additional refinements, the *in vitro*procedure potentially is a faster and more efficient way to initially screen kochia populations for resistance to dicamba than traditional whole plant response testing.

Herbicide-Resistant Kochia scoparia in Eastern Colorado. Eric P. Westra*, Scott J. Nissen; Colorado State University, Fort Collins, CO (023)

A field survey was initiated in the fall of 2011 to establish the occurrence and frequency of glyphosate resistant kochia in Eastern Colorado. Surveys were also conducted in 2012, and 2013 to evaluate the development and spread of glyphosate resistance over three years. Kochia samples were collected from geo-referenced field locations in the fall of each year. The majority of kochia samples were collected from chemically fallowed fields. Collected kochia seeds were vernalized in the cold room for several months before they were seeded, and grown in the greenhouse for herbicide screening. Plants at the 4-6 inch growth stage were sprayed with glyphosate (Roundup WeatherMAX®) at 0.75 lb ae/A + AMS at 17 lbs/100 gal. For each population 54 individual kochia plants were screened to establish the level of resistance within the populations. Plant mortality was evaluated 21 days after herbicide treatment, and populations were classified resistant if greater than 20% of the individuals survived the field rate of glyphosate. In 2011, approximately 12% of populations tested were classified resistant based on >20% survival, whereas in 2012 close to 43% of populations tested were classified resistant. This trend suggests that the occurrence of glyphosate resistant kochia in Eastern Colorado has increased significantly over one year. Evaluation of 2013 samples will indicate whether there is an additional increase in the development or spread of glyphosate resistant kochia, and the three year study will serve to establish a baseline level of glyphosate resistant kochia in Eastern Colorado for future comparisons.

Control of Kochia in Tame Mustard with Spring or Fall Sulfentrazone. Daniel Ulrich*, Eric Johnson, Greg Ford, Cindy Gampe; Agriculture and Agri-Food Canada, Scott, SK (024)

Limited options for broadleaf weed control in tame mustard have prevented expansion of mustard acres on the Canadian prairies. Following the selection of kochia (*Kochia scoparia*) in tame mustard as a national priority at the 2009 Canadian Minor Use Pesticide meeting field trials were initiated at the Research Farm located at Scott Saskatchewan. Trial work from 2011 to 2013 evaluated tame mustard tolerance to various use patterns of sulfentrazone and added control ratings to an existing sulfentrazone-kochia data set with the objective of assessing sulfentrazone's potential to provide acceptable tame mustard tolerance with effective kochia control. Sulfentrazone timing (spring or fall), sulfentrazone rate (0 to 210 g ai/ha) and sulfentrazone with or without fall dinitroaniline (ethafluralin or trifluralin) results showed sulfentrazone rate had the greatest impact on visual crop injury (stunting, chlorosis, plant loss) and seed yield (P=0.05) but was dependant on mustard species as well as May-June precipitation level. The sulfentrazone maximum safe rate (MSR) for yellow mustard (*Sinapis alba* L.) was 140 g ai/ha under normal spring precipitation of 108 mm. Under above normal spring precipitation (150 mm) the sulfentrazone MSR for yellow mustard declined to 105 g ai/ha as compared to a sulfentrazone MSR of 140 g ai/ha for oriental mustard (*Brassica juncea* L.) and Ethiopian mustard (*Brassica carinata* L.). The sulfentrazone MSR range of 105 to 140 g ai/ha under normal to above normal spring precipitation for tame mustard and acceptable control of kochia at 62 g ai/ha that was established from 33 site years of data revealed a broad sulfentrazone rate range that combines acceptable crop safety with effective kochia control. However under much above normal spring precipitation (255 mm) an increase in tame mustard injury resulted in the loss of an observed sulfentrazone safe rate for Ethiopian mustard.

How Soil Salinity Affects Herbicide Resistant Kochia Managment in the Upper Great Plains.
Mike H. Ostlie*, Gregory Endres; North Dakota State University, Carrington, ND (025)

Herbicide resistance development in kochia is a threat to most crops produced in the Great Plains. It does not stop there. There are more acres affected by salt in North Dakota than there are in production of any single crop. Due to the reduced economic potential of salt-affected soils, these regions are often neglected or managed differently than more productive areas. Kochia is inherently salt tolerant, making it one of the few species able to grow deep into salt-affected regions, leaving little-to-no interspecies competition for resources. Management decisions become more difficult when soil health is taken into account since tillage promotes evaporation and salinity while also being one of the few effective kochia control options remaining. The combination of unlimited growth potential in kochia and less management in saline areas leads to a troubling scenario where herbicide resistance traits proliferate and comingle. Future management goals in saline regions need to include steps to prevent kochia seed production while positively affecting soil health. These strategies need to consider many aspects of kochia biology; timing kochia removal/control before flowering, preventing plants from blowing and dispersing seed, and managing the area aggressively for at least three years to eliminate viable kochia seed from the soil seed bank. Simultaneous efforts need to be exerted to reduce soil salinity and improve crop productivity to prevent future kochia infestations.

Target-Site and Possible Non-Target-Site Multiple-Herbicide Resistance in Kochia from Kansas. Amar S. Godar*[1], Vijay K. Varanasi[1], Randall S. Currie[2], Anita Dille[1], Curtis Thompson[3], Phillip W. Stahlman[4], Mithila Jugulam[1]; [1]Kansas State University, Manhattan, KS, [2]Kansas State Univ., Garden City, KS, [3]Kansas State, Manhattan, KS, [4]Kansas State University, Hays, KS (026)

Kochia (*Kochia scoparia*) is a problem weed in of the US Great Plains and has been historically prone to evolve resistance to herbicides. We recently found kochia biotypes from Garden City

(GC), KS, which survived field applications of several herbicides with different modes of action. The objectives of this study were to (1) characterize resistance to atrazine, chlorsulfuron and glyphosate in four kochia biotypes (GC1, GC2, GC3, and GC4), and (2) to investigate if target-site and/or non-target-site mechanisms determine resistance to above herbicides in GC biotypes. Six individual plants (10-12 cm tall) from each biotype were treated with 0.25-, 0.5-, 1-, 2- and 4-X labeled use rates of atrazine, chlorsulfuron, and glyphosate including recommended adjuvants. The dose-response results indicated that all GC biotypes were resistant to chlorsulfuron and glyphosate, and only GC1 was resistant to atrazine. Genomic DNA was isolated from all GC biotypes and gene specific primers were used to amplify *psbA*(encodes D1 protein of PSII), acetolactate synthase (*ALS*), and 5-enolpyruvylshikimate-3-phosphate synthase (*EPSPS*) genes, the target sites of atrazine, chlorsulfuron and glyphosate, respectively. The PCR amplified fragments were sequenced. Furthermore, the *EPSPS* gene copy number relative to *ALS* (reference gene) was also determined using quantitative PCR. The nucleotide sequence analysis revealed no known mutations in the *ALS* gene in our GC1, GC2, and GC4 biotypes. However, a single point mutation involving substitution of proline (CCG) with threonine (ACG) at position 197 of *ALS* gene was observed in GC3 biotype, suggesting the presence of target-site resistance specific to sulfonylurea herbicides. A single point mutation involving substitution of serine (AGT) with glycine (GGT) at position 264 of the *psbA* gene was found in GC1 and as expected from dose-response results, not in other biotypes. *EPSPS* gene sequence showed no proline 106 mutations in any of our GC kochia biotypes. Nevertheless, increased copies of *EPSPS* gene (5-9 copies) were found in all GC biotypes. Experiments are in progress to confirm whether the *ALS* resistance in GC biotypes (1, 2 and 4) is due to non-target site mechanisms or a novel target-site mutation. Multiple herbicide resistance in kochia is a serious threat to sustainable agriculture, especially in no-till system.

Giant Ragweed Resistance to Glyphosate in Nebraska. Stevan Z. Knezevic*[1], Jon E. Scott[1], Avishek Datta[2]; [1]University of Nebraska - Lincoln, Concord, NE, [2]Asian Institute of Technology, Bangkok, Thailand (027)

Extensive use of glyphosate and Roundup Ready crops has changed farming practices over the last 15 years. Repeated use of glyphosate on over 100 million hectares has developed glyphosate resistance in 13 weed species in the United States. The current suspected glyphosate resistant (GR) giant ragweed population was found in a corn and soybean production system with history of glyphosate use for weed management in David City, NE. Therefore, field experiments were conducted in 2012 and 2013 to determine the level of glyphosate resistance in the suspected GR giant ragweed population in David City, NE. The experiments were conducted twice with four replications. Trial by treatment interactions was not significant therefore; data were combined over experimental runs and years. Weed control was assessed visually at 7, 14, and 21 DAT, and dry matter data was recorded. Dose response studies were conducted with five glyphosate rates (0, 1X, 4X, 8X, and 16X of label rates) applied postemergence at two application timings (10 and 20 cm). Glyphosate resistance was determined by the ED_{80} and ED_{90} values of the population. The estimated level of glyphosate resistance based on ED_{90} values at 21 DAT for 10 and 20 cm tall giant ragweed was 14X and 36X, respectively. To achieve 90% control of this population, at least 14 times the label use-rate (1060 g ai/ha) was needed, indicating that the suspected giant ragweed population was glyphosate-resistant.

Waterhemp Resistance to Post Emergent Application of HPPD Herbicides. Stevan Z. Knezevic*[1], Jon E. Scott[1], Aaron S. Franssen[2], Vinod K. Shivrain[3]; [1]University of Nebraska - Lincoln, Concord, NE,[2]Syngenta Crop Protection, Seward, NE, [3]Syngenta Crop Protection, Vero Beach, FL (028)

Crop production systems in the United States are facing a major challenge with increasing number of weed species evolving resistance to herbicides. In 2009, waterhemp (*Amaranthus tuberculatus syn. rudis*) biotypes resistant to HPPD-inhibiting herbicides were first reported in Iowa and Illionois. Waterhemp has been reported to be resistant to three mechanism of actions in Nebraska; PSII, HPPD, and synthetic auxins-inhibiting herbicides. Field studies were initiated in 2012 and 2013 to determine level of waterhemp resistance to post-emergent applications of HPPD-inhibiting herbicides in a population reported from Nebraska. A total of five doses (0, 1X, 2X, 4X, and 8X) of suggested label rates of mesotrione, tembotrione, and topramezone were applied at two application timings (8 and 15 cm). Weed control was visually evaluated weekly until 26 DAT, and weed dry matter was recorded. Based on visual injury and dry matter reduction, dose response analysis was performed to determine ED_{50}, ED_{60}, and ED_{80} values for control of 8 and 15 cm tall waterhemp with mesotrione, tembotrione, and topramezone. The estimated level of resistance at 26 DAT for 15 cm tall waterhemp to mesotrione, tembotrione, and topramezone was 13, 10, and 7 times the label rate, respectively. While levels of resistance to tembotrione and topramezone were not as high as mesotrione, the population was confirmed to be resistant. The use-pattern of HPPD herbicides should be carefully managed and an integrated weed management plan involving tillage and multiple mechanism of actions should be utilized.

Identification of Herbicide-Resistant Barnyardgrass (*Echinochloa crus-galli*) Biotypes in Korea. Kee Woong Park*; Chungman National University, Daejeon, South Korea (029)

The continuous use of acetolactate synthase (ALS) and acetyl-CoA carboxylase (ACCase) inhibiting herbicides has led to the selection of herbicide resistant barnyardgrass populations in direct-seeded rice fields of Korea. This study was conducted to identify herbicide resistance of barnyardgrass biotypes and to determine the cross- and multiple-resistance of them. 25% of the population collected from Taeahn was partially resistant to ACCase inhibitors and 22% collected from Kimjae were partially resistant to ALS inhibitors. However, 8.2% of the population from both sites was resistant to ALS and ACCase inhibitors. Resistance to sulfonylurea herbicide (flazasulfuron) was identified from two barnyardgrass accessions collected from both Taeahn and Kimjae. One barnyardgrass accession from both Taeahn and Kimjae was resistant to ACCase herbicide (sethoxydim). The cross-resistance to ALS inhibiting herbicides was identified at one barnyardgrass accession from Taeahn and at two accessions from Kimjae. Further, cross-resistance to ACCase inhibiting herbicides was also identified at two barnyardgrass accessions from Taeahn and one accession from Kimjae. Multiple-resistance to ALS inhibiting herbicide (flazasulfuron) and ACCase inhibiting herbicide (sethoxydim) were determined at four barnyardgrass accessions from Taeahn and at six accessions from Kimjae. Therefore, the herbicide mixture and sequences within a growing season or the herbicide rotation with different modes of actions across growing seasons are recommended to control herbicide-resistant barnyardgrass in infested fields.

Light-Activated Sensor Controlled Sprayer (Weed Seeker®) for Cost-Effective Weed Control in Post-Harvest Wheat Stubble. Prashant Jha*, Aruna Varanasi, Vipan Kumar, Shane Leland; Montana State University, Huntley, MT (030)

Field experiments were conducted at the Montana State University Southern Agricultural Research Center near Huntley, MT, in 2013, to evaluate effectiveness of light-activated sensor-controlled (LASC) sprayer (WeedSeeker®) vs. conventional broadcast sprayer for weed control in post-harvest wheat stubble. A 1.5-m, ATV-mounted, spray boom was fitted with five LASC spray units equipped with flat-fan nozzles spaced 30 cm apart. Both of the sprayers were calibrated to deliver 94 L ha^{-1} of spray solution at 276 kPa. Plots (2.5 m wide by 9 m long) were established following winter wheat harvest in the fall, and broadcast and LASC spray plots were established side by side for comparison. The weeds present at the test site were kochia and prickly lettuce. The study was established in a randomized complete block design with three replications for each herbicide treatment. Savings in herbicide (plus recommended adjuvants) volume and cost using LASC technology vs. broadcast application were calculated.Kochia and prickly lettuce control did not differ between LASC and broadcast application for the POST herbicides tested. Paraquat (48 fl oz/acre), paraquat (32 fl oz/acre) + linuron (16 fl oz/acre), and saflufenacil (1.5 fl oz/acre) + 2, 4-D (16 fl oz/acre) provided greater control (92 to 100%) of kochia and prickly lettuce among all herbicide programs, 14 and 28 DAA. Glyphosate @ 64 fl oz/acre was more effective in controlling kochia (97%) and prickly lettuce (91 to 93%) compared with glyphosate at 22 and 32 fl oz/acre, applied postharvest in wheat stubble. Kochia control with pyrasulfotole + bromoxynil (15 fl oz/acre) (85 to 96%) did not differ from glyphosate (32 oz/a) alone or glyphosate (22 fl oz/acre) + dicamba (8 fl oz/acre) + 2, 4-D (16 fl oz/acre) (85 to 88%) 28 DAA. However, pyrasulfotole + bromoxynil was more effective (96 to 98%) compared with glyphosate + dicamba + 2, 4-D (80 to 85%) on prickly lettuce control 28 DAA. Control of kochia and prickly lettuce was least with dicamba (8 fl oz/acre) + 2, 4-D (16 fl oz/acre) (47 to 52%), followed by carfentrazone (2 fl oz/acre) + dicamba (8 fl oz/acre) (63 to 72%), and diflufenzopyr + dicamba (2 oz/acre) + 2, 4-D (16 fl oz/acre) (68 to 77%). Also, for each herbicide treatment, shoot dry weight response of kochia treated with LASC and broadcast spray did not differ, and was consistent with percent control ratings. LASC sprayer reduced the herbicide usage by 45 to 67%. Furthermore, there was 45 to 62% savings in herbicide (plus adjuvant) cost using LASC spray technology. This research suggests that LASC (WeedSeeker®) sprayer would allow growers to apply higher rates of an herbicide and additional tank-mixtures to effectively control weed escapes or herbicide-resistant weeds in chemical-fallow or post-harvest wheat stubble, with savings in herbicide use and cost.

Foxtail Barley Control in Wheat. Brian M. Jenks*, Tiffany D. Walter, Gary P. Willoughby; North Dakota State University, Minot, ND (031)

Abstract not submitted

Anthem FLEXTM: A New Tool from FMC for the Management of Key Weed Pests in Spring and Winter Wheat. Terry W. Mize*; FMC Corp, Olathe, KS (032)

Anthem Flex*tm* is a new premixture herbicide in development by FMC Corporation as a premium weed management tool in small grains and other crops, including cotton, dry beans, peanuts, and potatoes. Research trials conducted in North America from 2011 to 2013 on both Anthem^{tm} and Anthem Flex^{tm} have shown the value of both new products for control of many key broadleaves and grasses in wheat, and especially for the management of resistant Italian Ryegrass, Lolium multiflorum (LOLUM). LOLUM incidence and severity has been growing across the wheat growing regions of the U.S. over the last 10 to 15 years, and is now one of the most challenging threats to wheat production, particularly in the Pacific Northwest and Southern areas of the Great Plains. LOLUM resistance to glyphosate is found in most areas of the U.S. and other locations around the globe, as well as to ACCase and ALS-inhibiting herbicides[1]. Anthem Flex^{tm} was shown in this multiple-year research program conducted by both FMC and University research personnel as an extremely effective tool for the management of LOLUM in wheat and as a new mode of action critical to the management of LOLUM resistance to other modes of action. Anthem Flex^{tm} had also been tested in both the U.S. and Canada as a potential tool for management of other problematic grass weeds in spring and winter wheat, including Bromus spp., Setaria spp., and Wild Oats. Results have shown that Anthem^{tm} or Anthem Flex^{tm} at sufficient rates are capable of delivering good control of these and other weed pests in wheat with good crop tolerance and provides an addtional herbicide mode of action essential for resistance managment of existing and new hericides in smll grains. Anthem Flex^{tm} is under review for in the U.S., and is has a tentative USEPA registration set for the 3Q of 2014.

Winter Wheat Tolerance and Grass Weed Efficacy with Pyroxasulfone Combinations. Traci Rauch*, Joan Campbell, Donn Thill; University of Idaho, Moscow, ID (033)

Rattail fescue and Italian ryegrass are important weeds in wheat cropping systems in the Pacific Northwest. Rattail fescue is a significant problem in conservation tillage systems and is difficult to control with glyphosate. Italian ryegrass biotypes resistant to group 1 (ACCase) and group 2 (ALS) herbicides are widespread and few control options are available. Pyroxasulfone is a new active ingredient that is registered in winter wheat to control grass weeds. It is a group 15 herbicide that inhibits very long chain fatty acid synthesis. Studies were conducted in 2013 to evaluate winter wheat tolerance, rattail fescue and Italian ryegrass control with pyroxasulfone combinations. The experimental design in all studies was a randomized complete block with four replication. Pyroxasulfone was applied alone preemergence in the fall, tank mixed with other fall preemergence herbicides (flumioxazin or fluthiacet), or sequentially applied with spring postemergence herbicides (pyroxsulam, mesosulfuron, flucarbazone, or sulfosulfuron). Pyroxasulfone treatments were compared to flufenacet/metribuzin treatments, which is the current standard preemergence herbicide used to control rattail fescue and Italian ryegrass. Grass weed control and winter wheat response were evaluated visually where 0% represented no control or injury and 100% represented complete weed control or crop death. Pyroxasulfone/flumioxazin alone and combined with post emergence herbicides injured winter wheat 12 to 15% in studies where winter wheat was direct-seeded, and 6 to 29% in studies where winter wheat was seeded into a conventionally tilled seedbed. Winter wheat seed yield was reduced 13 and 22% by pyroxasulfone or pyroxasulfone/flumioxazin plus mesosulfuron, respectively, compared to the untreated check. All treatments containing pyroxasulfone or flufenacet/metribuzin controlled rattail fescue 98 to 99%. Pyroxasulfone alone or followed by pyroxsulam, pyroxasulfone/fluthiacet plus pyroxsulam and all pyroxasulfone/flumioxazin treatments controlled Italian ryegrass 89 to 99%.

Use of Pyroxasulfone for Weed Control in Clearfield® Wheat System. Prashant Jha*, Vipan Kumar, Aruna Varanasi; Montana State University, Huntley, MT (034)

Field experiments were conducted at the MSU Southern Agricultural Research Center near Huntley, MT, to compare downy brome control with pyroxasulfone and other standard herbicide programs in Clearfield® winter wheat. Pyroxasulfone (89.25 g ai ha^{-1}) was applied preemergence (PRE) only or PRE (89.25 g ai ha^{-1}) followed by imazamox postemergence (POST). Standard programs included propoxycarbazone-sodium (29.4 g ai ha^{-1}) applied PRE only or followed by imazamox (43.75 g ai ha^{-1}) POST, imazamox (43.75 g ai ha^{-1}) POST only, and pyroxsulam (18.58 g ai ha^{-1}) POST only. PRE herbicides were applied in the fall of 2011 and 2012 at planting, and POST herbicides were applied to 3- to 4-tiller Clearfield® winter wheat in the spring of 2012 and 2013. POST imazamox applications included MSO (1% v/v) and UAN and pyroxsulam applications included NIS (0.5%v/v) and UAN. Herbicides were applied with a hand-held boom calibrated to deliver 94 L ha^{-1} at 276 kPa. Treatments were arranged in a randomized complete block design with four replications. No wheat injury was observed with any of the herbicides, including pyroxasulfone. Averaged over years, downy brome end-season control with pyroxasulfone PRE followed by imazamox POST was 99%, which was superior to all other treatments, except propoxycarbazone PRE followed by imazamox POST program. End-season control with pyroxasulfone PRE only was comparable to propoxycarbazone PRE only; however, it was superior to the control obtained with pyroxsulam POST only program. Wheat yield with pyroxasulfone or propoxycarbazone PRE followed by imazamox POST was higher than all other treatments, and averaged 2,873 kg ha^{-1}. Wheat yield was least with imazamox or pyroxsulam POST only program, and averaged 1701 kg ha^{-1}. Even in the absence of a POST program, a 2.3-fold increase in wheat yields was observed with pyroxasulfone or propoxycarbazone PRE only program compared with the weedy check treatment. In conclusion, pyroxasulfone applied PRE (fall) followed by imazamox POST (spring) will be an effective strategy to manage downy brome infestations in Clearfield® winter wheat.

Alfalfa Crop Rotation with Pyroxsulam. Joe Yenish*; Dow AgroSciences, Billings, MT (035)

Irrigated growers in the Pacific Northwest often plant cereal grains just prior to an autumn seeding of alfalfa. The early harvested cereal allows for an optimal timing of alfalfa seeding. Soil persistent herbicides used in cereal crops could damage alfalfa germination and establishment. Trials were conducted at Kimberly, ID; Ontario, OR; and Othello and Prosser, WA to evaluate alfalfa establishment when seeded 4 months after applications of pyroxsulam, fluroxypyr plus florasulam, and sulfosulfuron at 1, 2, and 4 times labeled rates. Pyroxsulam was applied as PowerFlex HL™ at 18.4, 36.8, and 73.6 g ai/ha tank mixed with nonionic surfactant at 0.5, 1.0, and 2.0% v/v and ammonium sulfate at 1.7, 3.4, and 6.8 kg/ha, respectively. Fluroxypyr plus florasulam were applied as Starane Flex™ at 99 plus 5, 198 plus 10, and 396 plus 20 g ae fluroxypyr plus florasulam ai/ha, respectively. No adjuvants were applied with any Starane Flex™ treatments. Sulfosulfuron was applied as Maverick at 35, 70, and 140 g ai/ha tank mixed with nonionic surfactant at 0.5, 1.0, and 2.0% v/v, respectively. Sulfosulfuron was included as a reference comparison treatment which was expected to result in alfalfa injury. Visual estimate of growth inhibition 4 weeks after planting (WAP) at ID and OR locations were less than 2% for 1 and 2x applications of pyroxsulam and all treatments of fluroxypyr plus florasulam. Growth inhibition with the 4x rate of pyroxsulam was less than 10%. Sulfosulfuron treatments averaged 7.5, 10.6, and 20.6% growth inhibition for the 1, 2, and 4x rates, respectively. Stand density measurements 6 WAP showed alfalfa plant densities for all pyroxsulam treatments within 6% of the non-treated for the same replication. Alfalfa seedling densities with fluroxypyr plus florasulam treatments were all within 2.5% of the non-treated with sulfosulfuron treatments having stands of 95.4, 87.7, and 96.4% of the non-treated for the 1, 2, and 4x rates, respectively. Stand densities 35 WAP in ID and OR showed reductions not greater than 7.5% for 1 and 2x rates of pyroxsulam with the 4x rate having a stand reduction slightly greater than 15%. Stands reductions across the fluroxypyr plus florasulam treatments ranged from 1.5 to 3.6% while reductions with sulfosulfuron ranged from just under 15 to just over 20%. Alfalfa 1st cutting yields for 1, 2, and 4x rates of pyroxsulam were 109, 95, and 104% of the non-treated, respectively. All fluroxypyr plus florasulam treatments had slightly increased 1st cutting yields, ranging from 103 to 108% of the non-treated. All sulfosulfuron treatments yielded less than the non-treated with a range of 87 to 95% of the non-treated. Second cutting harvest for all herbicide treatments exceeded that of the non-treated. The initial year's data support a 4-month plant back restriction for pyroxsulam or fluroxypyr plus florasulam with at least a 2X margin of safety in irrigated systems.

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Lentil Tolerance to 2,4-DB Tank Mixes. Louise H. Lorent*[1], Edward Davis[2], Brian Jenks[3], Ian C. Burke[1]; [1]Washington State University, Pullman, WA, [2]Montana State University, Bozeman, MT, [3]North Dakota State University, South Minot, ND (036)

Herbicide options for broadleaf weed control in lentil are limited. Several legume crops such as alfalfa, soybean and peanut have tolerance to 2,4-DB, a systemic phenoxyacetic acid herbicide, but lentil response to 2,4-DB has not been studied. Experiments were established in 2012 and 2013 in Washington and in 2012 in Montana to evaluate response of lentil to 2,4-DB alone and in mixture with clethodim. Experimental design was a three factor factorial. The first factor was dose of 2,4-DB (420 g ai ha^{-1} or 840 g ai ha^{-1}). The second factor was clethodim application (2,4-DB was applied alone followed by clethodim plus COC, applied with NIS followed by clethodim plus COC, or mixed with clethodim plus COC). The third factor was timing of 2,4-DB application: a first series of treatments was applied when lentil canopy was 5 to 10 cm tall and a second series was applied when lentil canopy was 15 to 20 cm tall. Treatments also included a weed-free nontreated check. Lentil injury was evaluated throughout the growing season. In 2012 in Montana and Washington grain yield was harvested using a small plot combine while in 2013 in Washington total crop biomass was taken per plot using two 1 m^2 quadrats. In North Dakota, there was a significant three-way interaction of factors on late season injury. Injury was greater when 2,4-DB was applied early and applied with NIS or COC plus clethodim. In Montana, injury and yield loss were greater with higher doses of 2,4-DB, when applications were made early and when 2,4-DB was tank-mixed with NIS or COC plus clethodim. Lentil yield was reduced as much as 92% compared to the nontreated check. In Washington in 2012 and 2013, timing of application did not affect end-of-season biomass. However, a high dose of 2,4-DB reduced yield almost twice as much as a low dose of the herbicide, and the addition any surfactant resulted in greater yield loss than

2,4-DB applied alone. Applications of 2,4-DB reduced yield by as much as 85% in 2012, and reduced total biomass by as much as 64% in 2013. Additional studies were conducted in Montana and North Dakota to evaluate efficacy of 2,4-DB used in lentil for control of several weed species. In Montana, 2,4-DB applied at 420 g ai ha^{-1} or 840 g ha^{-1} provided >95% levels of control of lambsquarters but marginal levels of control of kochia (<57%) and Russian thistle (<70%). In North Dakota, >90 % control of common lambsquarters was achieved with 2,4-DB at 420 g ai ha^{-1} plus COC or NIS, but only 50% when 2,4-DB was applied alone. The same dose of 2,4-DB applied with NIS or COC provided >60% control of prickly lettuce and horseweed, but control fell below 36% when 2,4-DB was applied alone. Control of kochia in North Dakota did not exceed 32%. Crop injury and yield loss indicate that 2,4 DB would not be a viable tool for weed control in lentil.

Project 4. Teaching and Technology Transfer

Manual for Propane-Fueled Flame Weeding in Corn, Soybean, and Sunflower. Stevan Z. Knezevic*[1], Avishek Datta[2], Chris Bruening[3], George Gogos[3], Jon E. Scott[1]; [1]University of Nebraska - Lincoln, Concord, NE, [2]Asian Institute of Technology, Bangkok, Thailand, [3]University of Nebraska - Lincoln, Lincoln, NE (038)

Flame weeding is an approved method for weed control in organic cropping systems, with the potential for use in conventional agriculture. From 2006-2012 we have conducted a series of over 40 studies, which were funded by PERC and other sources (eg. USDA). This extensive work resulted in over 20 journal and proceeding articles about crop tolerance to heat and weed control with flame weeding in field corn, popcorn, sweet corn, sunflower, soybean, sorghum and winter wheat. We compiled the above research information into a training manual that describes the proper use of propane fueled flaming as a weed control tool in six agronomic crops (field corn, popcorn, sweet corn, soybean, sorghum, and sunflower). Flame weeding manual contains 32 pages of text and color pictures. The pictures provide visuals of crop growth stages when flaming can be conducted safely without having side-effects on crop yield. Pictures of weeds provide visuals of appropriate growth stages when weeds need to be flamed to achieve good weed control. There are six chapters in the manual: (1) The need for alternative weed control methods; (2) Propane fueled-flame weeding; (3) How flame weeding works; (4) Equipment and configurations; (5) Propane dosage at different weed growth stages, and (6) Crop Tolerance to post-emergent flame weeding. We believe that our manual provides a recipe on how to use flaming procedures and it is written in a user friendly manner that can be understood by the general public. Manual is free, it can be downloaded in a pdf format from the following website:

http://www.agpropane.com/ContentPageWithLeftNav.aspx?id=1916

Herbicide Treatment Cost Calculation Model. Bryan Dayton*, Ralph E. Whitesides; Utah State University, Logan, UT (039)

Herbicide treatment bids are based primarily on acreage without taking into account variables that increase treatment time and cost. Often neither the agency contracting the project nor the contractor has a clear idea of the costs involved. This makes it difficult to seek funds and to budget for noxious weed control. A partnership was established between the Department of Plants, Soils, and Climate at Utah State University and Providia Management Group (PMG Environmental) to evaluate herbicide treatment data over several seasons. In 2013, PMG's backpack crews treated hundreds of acres in Utah and Idaho. Using a "smart" spray wand (patent pending) and backpack equipment, PMG gathered millions of data points including a GPS point each time a weed was sprayed. Each GPS data point included the GPS location, herbicide flow, elevation, and application time. Terrain information for modeling was obtained using the Gap Analysis Program (GAP) land cover map. Slope was obtained from 10 m DEM's from the U.S. Geological Survey. Treatment time per area, and weed density were determined to evaluate the relationship between the variables. A model has been developed that can predict herbicide application time. This model will assist land managers and contractors in developing reasonable bids for weed treatments.

Influence of Sensor Accuracy on Statistical Conclusions. Dirk V. Baker*[1], Jody A. Swenson[2]; [1]Campbell Scientific, Inc, Logan, TN, [2]Campbell Scientific, Inc, Logan, UT (040)

Measurement error attributable to measurement systems themselves is rarely considered in experimental design or statistical analyses in agricultural and ecological sciences. Yet these error sources are relatively well-known and quantifiable. We used air temperature measurements collected in northern Utah to illustrate magnitudes of measurement errors. Broadly speaking, uncertainty in air temperature measurement can be classified into three categories: (1) error explicitly related to the measurement system (sensor and datalogger), (2) error from direct solar radiation (lack of a radiation shield) and (3) error from solar loading (difference between standard radiation shielding and a fan-aspirated radiation shield). For the first category, we used Monte-Carlo methods to derive error estimates based on specifications of the equipment used. We also co-located three temperature probes; one without shielding of any kind, one with standard gill-style radiation shielding, and one with a fan-aspirated radiation shield. Data collected from each probe clearly show that errors can amount to several degrees Celsius even under low radiation and low solar angle conditions (winter in northern Utah). The majority of this error is due to radiative effects. It is important to note that variation in replicated data is potentially additive to measurement error and was not considered here. We strongly recommend that measurement error be seriously considered both in experimental design (analogous to statistical power analysis) and analysis stages in research, or any other datasets that seek to elucidate site differences or trends over time. *A priori* decisions about what differences or trends are important to detect will be strong guides to choice of measurement design and deployment.

Project 5. Basic Biology and Ecology

Effect of Prescribed Fire on Buckbrush Vegetative Reproductive Mechanisms. John D. Scasta*, David M. Engle; Oklahoma State University, Stillwater, OK (041)

Buckbrush (*Symphoricarpos orbiculatus*) is the dominant shrub of tallgrass prairie and reproduces sexually and asexually. *S. orbiculatus* forms large colonies with mature height less than 2 meters. Perceived competition with herbaceous plants has led to chemical and mechanical control

recommendations. However, restoring a functioning fire-regime is fundamental to mediating shrub invasion and could sustain this functional shrub component for wildlife while maintaining herbaceous plants important for cattle forage. From 2011 to 2013, we assessed how *S. orbiculatus* basal re-sprouting and layering stems were affected by patchy fires, complete pasture fires or long-term fire exclusion. At 120 days after burning we measured plant height, stem density, plant density, canopy cover, and probability of layering stems. Maximum height in recently burned plots was significantly lower than unburned control plots. However, *S. orbiculatus* in burned plots reached ~70% of pre-burned height by 120 days after fire. Stems per plant density were approximately 2x greater in the most recently burned plots as a result of prolific basal re-sprouting. Canopy diameter and density of *S. orbiculatus* plants was not affected by time since fire. However, fire triggered formation of layering stems, and as time since fire elapsed, probability of layering stems decreased ($P = 0.001$) and no layering stems were found in plots not burned for > 3 years. This suggests that *S. orbiculatus* is fire tolerant because the species possesses several regeneration mechanisms following fire. Recurring fire did not result in substantial mortality, but recurring fire reduced structural height dominance and invigorated decadent stands.

Weed Seedbank Density Effects on Pendimethalin Control Outcomes. Ashley E. Cunningham*, Brian J. Schutte; New Mexico State University, Las Cruces, NM (042)

Chile pepper production is challenged by a prolonged period in which weeds must be controlled to maintain maximum yield potential. During midsummer, weed control can be provided by pendimethalin, a pre-emergence herbicide that is applied after emergence of the chile crop. Understanding factors that influence the ability of pendimethalin to suppress weeds will enable producers to design systems for weed management that improve pendimethalin efficacy. The objective of this study was to quantify the response of pendimethalin efficacy to increasing densities of germinable seeds of yellow foxtail (*Setaria glauca*) and tall morningglory (*Ipomeoa purpurea*). To address this objective, field studies were conducted at two university research farms located in central and southern New Mexico. At each site, soil seedbanks were augmented with 500, 1500, 2500, 3500, or 4500 yellow foxtail seeds m^{-2} or 15, 30, 60, 120, or 240 tall morningglory seeds m^{-2}. To account for spatial variability in ambient seedbanks, each seedbank augmentation treatment was coupled with non-augmented control plots. After seeding, pendimethalin was applied at the label rate for chile pepper, with consideration of local soil type (1.6 kg ai ha^{-1} for clay loams and 0.8kg ai ha^{-1} for sandy clay loam). Seedling emergence data indicated that seedbank density effects on pendimethalin control outcomes were influenced by species. For yellow foxtail, seedling densities at 28 days after application (DAA) were not associated with increasing seedbank augmentation level. For tall morningglory, seedling densities at 28 DAA increased asymptotically in response to increasing seedbank augmentation level. These results indicate that germinable seedbank densities impact pendimethalin control outcomes for tall morningglory but not for yellow foxtail. Accordingly, management practices that target weed seedbanks can be expected to improve pendimethalin suppression of tall morningglory, but such practices may not influence the ability of pendimethalin to control yellow foxtail.

Supplementing Corn Stalk Grazing with Winter Forage Crops. Jenna Meeks*[1], Brian A. Mealor[2], David A. Claypool[2], Andrew R. Kniss[2]; [1]University of Wyoming, Lingle, WY, [2]University of Wyoming, Laramie, WY (043)

Cattle in southeastern Wyoming commonly graze cornstalks during winter months. Corn residue has low forage quality compared to grasses in pasture systems and quality of corn stalk quality steadily declines throughout the winter. A field study was initiated in the fall of 2013 to determine whether fall-seeded forage crops can improve forage quantity and nutritional value for winter grazing. Forage crops were planted into an existing corn crop at approximately 12 d intervals between September 2 and October 30 to determine the impact of planting date on winter forage biomass. The study was conducted using a randomized complete block design with 6 planting dates per block and 4 replicates. The seed mixture included annual ryegrass, crimson clover, rapeseed, turnip, and radish. Aboveground biomass was collected from $1m^2$per plot between December 20 and January 10, dried at 60 C for 48 hr, and weighed. Digital photographs were taken of each plot at approximately monthly intervals. SamplePoint software was used to determine percent ground cover by overlaying a 100-point grid over an image and classifying each pixel as forage species, corn residue, or bare soil. Percent ground cover and biomass production collected at similar dates were highly correlated ($r=0.72$, $P<0.01$), indicating image analysis provided a non-destructive method for quantifying forage production. When sampled on November 20, forage cover decreased an average of 0.42% per day of delayed planting. Biomass from the earliest planting date averaged 80 kg/ha. Earlier planting dates will likely be required to obtain growth suitable for livestock grazing.

Characterizing the Seedbank in Native Rangeland Invaded by Downy Brome in Thunder Basin, Wyoming, USA. Shayla A. Burnett*, Brian A. Mealor; University of Wyoming, Laramie, WY (044)

Downy brome is one of the most significant invasive annuals in North America. Prior to its introduction, Western areas lacked a dominant native annual grass. Perennial species are not dependent on annual seed production as is downy brome, and rangeland seedbanks stand to be influenced by downy brome presence. We examined the plant community below- and aboveground at 7 rangeland sites currently or historically containing downy brome to provide insight on relationships between vegetation and seedbank dynamics. We based monitoring times on downy brome phenology sampling prior to fall 2011 cheatgrass emergence, after emergence but before summer 2012 seed rain, and after seed rain. We evaluated canopy cover, germinable seedbank, and total seedbank and calculated percent composition to compare across fractions. We confirmed many observations concerning rangeland seedbanks from previous studies: a disparity exists between below- and aboveground species composition, perennial grasses have small seedbanks, and annual grasses or forbs dominate the seedbank in a perennial rangeland community. At 6 sites, downy brome composed trace amounts to 9% of canopy cover, but downy brome did not dominate the seedbank. At the 7th site, there was higher downy brome cover, and downy brome phenology determined fraction dominance. This information can help identify a possible window in which to control downy brome to prevent seedbank dominance, and possibly inhibit site persistence or aboveground dominance. However, it may be limited in scope due to the described discrepancy between below- and aboveground communities and time-consuming nature of seedbank studies.

Endophyte Effects on Locoweed (*Astragalus mollissimus*) Growth Responses to Increasing Temperature and Intraspecific Competition. Brian J. Schutte*[1], Nina Klypina[1], Jamshid Ashigh[2]; [1]New Mexico State University, Las Cruces, NM, [2]Extension Weed Specialist/Assistant Professor, Las Cruces, NM (045)

Locoweeds are plants of the genera *Astragalus* and *Oxytropis* (Fabaceae family) and are toxic to cattle, sheep, and horses. The toxic property of locoweeds is the alkaloid swainsonine, which is synthesized by an endophytic fungus (*Undifilum* sp.) that is vertically transferred via seed coats. The *Undifilum*-locoweed symbiosis has not been shown to benefit host plants; however, the ecological consequences of the *Undifilum*-locoweed symbiosis were previously determined using seed coat removal treatments that may have had unintended consequences on plant growth and development. The objective of this experiment was to determine endophyte effects on *Astragalus mollissimus* above-ground growth responses to intraspecific competition and heat stress using endophyte-free (E-) and endophyte-containing (E+) plants produced from whole seeds. E- and E+ seedlings within an *A. mollissimus* population were identified using molecular techniques that were previously established. The competitive abilities of E- and E+ plants were then determined with a replacement series experiment conducted under greenhouse conditions for 6 months. A 5-month growth chamber experiment was used to measure E- and E+ plant biomass and leaf area under temperatures favourable (24 C day/17 C night; 12 h photoperiods) and unfavourable (32 C/27 C; 12 h photoperiods) for locoweed growth. Results indicated that E- and E+ plants did not have equal competitive ability as the above-ground biomass for E- plants was greater than the of above-ground biomass for E+ plants when the E- and E+ seedlings were planted in mixtures. When E- and E+ seedlings were planted in uniform stands, biomass accumulation of E- plants was similar to that of E+ plants. Above-ground biomass and leaf area were similar between E- and E+ plants grown under each of the temperature treatments. These results are consistent with previous studies that used seed coat removal treatments to produce E- and E+ plants. Furthermore, the results of this study are in agreement with previous studies that indicated the endophyte can limit locoweed growth under certain conditions.

Grazing and Disturbance Effects on Insect Seed Predators in Organic Field Crops. Greta G. Gramig*; North Dakota State University, Fargo, ND (046)

Post-dispersal weed seed predation by invertebrate granivores such as insects is often a key factor regulating weed population dynamics in annual cropping systems, but seed predation may be negatively affected by disturbances caused by field operations that occur mid-season. A four-year experiment was initiated during the spring of 2013 in Dickinson, ND to investigate how disturbances causing by mowing, harvesting, and sheep grazing would influence activity density of three key groups of insect seed predators (carabids, grasshoppers, and crickets) in an organic annual cropping system consisting of a five-crop rotation (each phase present in each year) and two tillage types (conventional-till and no-till). A secondary objective was to determine temporal variability in insect activity density. The Long Term Organic Tillage Study, which was initiated in 2012 at the NDSU Dickinson Research and Extension Center, was the site used to conduct this research. The experiment was arranged as a randomized complete block design with five replications of factorial combinations of crop (Proso millet, winter rye, field pea, hairy vetch/field pea, and winter wheat) and tillage type (conventional-till and no-till). Plot size was 30 x 9 m. To assess the impact of disturbances from mowing and grazing, as well as temporal effects, on insect activity density, two insect pitfall traps per plot were installed in various crop phases before and after these disturbances occurred. Traps were kept open for 48 hours per sampling period, and then trapped insects counted to determine insect activity densities. Insect trap data were collected from vetch/pea twice before mowing (7/12 and 7/15), from pea plots twice before harvesting (8/7 and 8/9), and from millet plots twice before mowing (7/3 and 7/5) and once after mowing (7/12). Traps were sampled post sheep grazing in millet and pea plots on 10/9. ANOVA tests were conducted to assess treatment effects (sampling date, disturbance, and tillage type (conventional-till or no-till) on grasshopper, carabid, and cricket insect activity densities (Proc Mixed SAS 9.3). Replication and crop type were included in the mixed models as random effects. Sampling date and disturbance both impacted grasshopper activity density, which was greater on July 12 than on other dates and was greater pre-disturbance than post-disturbance. Carabid and cricket activity densities were greatest on 8/9 and 7/12, respectively. Neither carabid nor cricket activity densities were affected by tillage type or disturbance. Insect trap data collected post-grazing were too scant to allow for statistical analysis. These results indicate that disturbances caused by mowing and harvesting may have species-specific effects on insect seed predators. Also, insect activity density can vary dramatically over short periods of time for various insect predators, with different species having peak activities at different times. Therefore, separating the effects of temporal variability from effects of disturbance will require inclusion of adequate experimental controls and sufficient sampling periods to capture temporal variability in insect activity. Assessing the possible impact of sheep grazing on insect predator activity will require conducting grazing operations during time periods when these insects are abundant and active.

Germination Rates of Three Invasive Annual Grasses. Sasha Twelker[1], Gustavo M. Sbatella*[2]; [1]Oregon State University, Madras, OR, [2]Oregon State, Madras, OR (047)

This study was conducted to compare seed germination rates under different temperature regimens of downy brome, medusahead, and ventenata from populations growing in Central Oregon. The optimum range of temperatures for seed germination of the downy brome population was 10/20 C. Temperatures of 10/20 C were also optimal for the germination of medusahead seeds, since the highest total germination (90%) was recorded at this set of temperatures. Results indicate that 5/10 C temperatures were optimal for seed germination for the ventenata population tested. Germination patterns observed for the three species from populations growing in Central Oregon suggest that the downy brome population has a clear advantage when it comes to seed germination when temperatures are above 10 C. This adaptive advantage is no longer evident when temperatures are below 10 C. Although downy brome seeds germinated faster than medusahead and ventenata, these two species germinated in higher proportion. Under these growing conditions, which are typical during early spring in Central Oregon, any factor that would affect a particular species can shift the balance towards the successful establishment of the others.

The Effects of Decreasing Soil Moisture on Seed Mortality of Palmer Amaranth (*Amaranthus palmeri*), Junglerice (*Echinochloa colona*) and Yellow Foxtail (*Setaria pumila*). Brian J. Schutte*, Nina Klypina; New Mexico State University, Las Cruces, NM (048)

Knowledge of the specific soil moisture conditions that accelerate weed seedbank loss will guide development of improved strategies for weed seedbank reduction in irrigated agriculture. Anecdotal evidence from previous studies suggests that soils near saturation are especially unfavorable for weed seed persistence; however, rates of weed seed loss under high soil moisture have yet to be determined. The objective of this study was to determine soil moisture level effects on the persistence of dormant and non-dormant seeds of Palmer amaranth, junglerice and yellow foxtail. Under laboratory conditions, seeds were buried in soil mesocosms that were hydrated to specific soil water potentials (0 kPa, -30 kPa, -60 kPa and -180 kPa). An additional soil moisture treatment included saturated soil under 1.5 cm of standing water ("flooded"). Hydrated mesocosms were placed in a growth chamber set to 35 C day / 25 C night, 12 hr photoperiods; conditions considered favorable for germination of the study species. At the conclusion of the incubation period (35 days), seeds were recovered and assessed for viability using a tetrazolium staining assay. Soil chemical analyses indicated that anaerobic conditions developed in flooded and 0 kPa treatments. For all other moisture treatments, aerobic conditions persisted throughout the study. Soil moisture effects on seed viability were influenced by seed type and weed species. With the exception of non-dormant junglerice seeds in the 0 kPa treatment, high rates of persistence (73 to 97%) were observed in saturated soil treatments (0 kPa and flooded). Soil moisture treatments -30 kPa, -60 kPa and -180 kPa greatly reduced persistence of non-dormant seeds of Palmer amaranth and yellow foxtail (17 to 20% persistence), and moderately reduced persistence of non-dormant junglerice seeds (56 to 63% persistence). Dormant seeds exhibited high rates of persistence (75 to 97%) under soil all moisture treatments. These results suggest that, for three weed species commonly found in agricultural environments in southern New Mexico, saturated soils are not required for large reductions in seedbank density. Accordingly, technologies that reduce the amount of water used for farmland irrigation have the potential to deplete weed seedbanks to levels at least comparable to seedbank depletion under traditional flood irrigation.

***Conyza canadensis* Tolerance to Glyphosate in the PNW.** Jessica Green[1], Ed Peachey*[2], Rick A. Boydston[3]; [1]Oregon State University, Corvallis, OR, [2]Oregon State University, 97331, OR, [3]USDA-ARS, Prosser, WA (049)

Burgeoning populations of horseweed, particularly along highways and in some cropping systems in western Oregon and the Columbia Basin of central Oregon and Washington, raised our curiosity about whether these populations might be resistant to commonly used herbicides such as glyphosate. Glyphosate resistant bio-types of horseweed are thriving in the central valley of CA, and movement of resistant biotypes to the PNW would significantly increase production costs in some cropping systems. We collected seed from mature horseweed plants at 11 sites in Western Oregon and 6 sites in the Columbia basin along major thoroughfares. Seeds were planted into pots in greenhouses, and seedlings sprayed with glyphosate at 0.5 and 1.0 lb ai/A. The experiment included a known susceptible from a site in CA, and each site was replicated 12 times. At 1 WAT there appeared to be very slight differences among seedlings from different sites in tolerance to glyphosate, but by 2 WAT, injury to seedlings at all sites were similar and eventually all treated plants died. Differences in response to glyphosate may have been due to differences in growth stage at application as there were very visible differences among the biotypes collected both in plant form and vigor. Leaf tissue samples were taken and tested using a patented Quick-Test™ (QT) solution and results indicated that all samples were susceptible to glyphosate. Overall, there appeared to be very little evidence that horseweed is resistant to glyphosate at label-recommended rates.

GENERAL SESSION

Presidential Address. Roger Gast*; Dow AgroSciences, Indianapolis, IN (051)

Welcome to the 67th Meeting of the Western Society of Weed Science. Our mission and objective is to foster cooperative research, education, and policy for weed management solutions throughout the western U.S. and Canada, and we've been doing that very well for the past 76 years (the Society first met in 1938 but did not meet every year until 1967).

The first thing I would like to do is thank all the people that have a hand in making this meeting successful. This includes Drew Lyon and his program committee, Tim D'Amato and his local arrangements team, our sustaining members, the breakfast and break sponsors, all the committee members, session chairs, and of course Phil Banks and his team. You can see that it takes a lot of service volunteers to run our society; and service volunteers and the active engagement of our membership will be the key to our future success.

As many of you know I currently reside in Indiana and have been for 14 years, and I'm sure some of you are wondering why I decided to become your president. To be sure, the western U.S. has always appealed to me from both a personal and professional interest. From the time I went to school in Nebraska and conducted my first weed science research study at the Scottsbluff research station, to managing our Dow AgroSciences research station in Fresno, California, I have been intrigued with the diversity of agricultural systems and unique weed control challenges the west offers. But it wasn't until about mid way through my weed science career that I attended my first WSWS meeting. I immediately noticed this society was different, in a very good way. Of course the level of science has always been top notch. What I was impressed with, and still am, is the level of cooperation and service that happens across a diverse membership that is truly motivated to deliver tangible weed control solutions. In a way the degree of geographic isolation and separation seems to bring us closer as an organization. I believe this spirit of cooperation is uniquely hardwired into our organization, through our structure of projects and committees, and how we conduct our meetings. Our vibrant discussion sessions are a good example of this. And we have society business meetings where most of the society attends! But the thing that really made me want to stay involved and make the WSWS my long term weed science home is the welcoming atmosphere we create.

I've always been a bit of a rolling stone, always looking for a new opportunity or challenge. Coming to our Dow AgroSciences headquarters in Indiana has allowed me to expand my sphere of influence in weed science and product development to a global level. The WSWS still continues to provide me with pertinent information and knowledge that I can take with me to all areas of the world. With our diverse ecosystems it seems like there is something that relates no matter where I go. The WSWS also keeps me grounded in the practical aspects of weed science necessary in my global role.

So again, why did I decide to become your president? It's really quite simple. It comes from my desire to serve a society that I think has meaning and purpose. Certainly I had to think twice about the commitment involved while having global job responsibilities - and maintaining family as a priority was an additional important consideration. But I know from my father's example, as he was president of the ASA while the Michigan State University Experiment Station Director, that it can be done. Also I've been around long enough to know that with leadership service you usually get many dividends (ie. new friends) in return, and are improved as person from the experience. My challenge to each WSWS member is to consider finding a way to serve the society whatever you do or wherever you are in your career. The future success of our society depends on a vibrant and serving membership. I recommend reading Dan Ball's 2009 presidential address for some good philosophical perspectives on leadership and service.

I would like to leave you with my perspectives on the future of weed science, particularly to the west. As you know weed problems are dynamic and always evolving and as soon as we think we have the solution Mother Nature shows us a new trick. So I think the need for the discipline of weed science is not going away anytime soon, but I think the way we approach it will be radically different in the future. Future solutions will come from seen and unforeseen technologies. Just think of the recent leaps and advancements in molecular biology and biotech techniques that have been enablers of the way we approach research to better understand plant systems. I believe with this deeper understanding we will be able to approach weed control in fundamentally different ways. For example, who would have thought about sprayable RNAi's just few years ago? These solutions will require both public and private innovation. Integrated approaches to research and solutions, both basic and applied, will be necessary. As has been the case in the past, these technologies may not be designed or targeted for our relatively small and specialized markets in the west. Therefore collaboration across WSWS membership will be needed even more in the future. I trust that we will be up for the challenge.

Thank you for giving me the opportunity to serve as your leader this past year. It's been an honor and a privilege.

WSSA and Regional Weed Science Societies - Director of Science Policy Update. Lee V. Van Wychen*; Weed Science Society of America, Alexandria, VA (052)

1. Generated support for **USDA research, education and extension funding** through competitive grants (AFRI), formula funds (Hatch, Smith-Lever) as well as integrated programs (Regional IPM): met with House and Senate committee staff and wrote coalition letters on behalf of the National and Regional Weed Science Societies. FY 2014 budget numbers are very good! NIFA is slated for $1.277 billion, which is over $100 million more than last year's sequester levels and the highest since 2010. AFRI will receive its highest appropriation ever of $316.4 million. The funding for federal land-grant capacity programs for research and extension will also receive some of the largest appropriations in recent memory. Smith-Lever 3b & c programs will get $300 million, the highest level in at least a decade. The same can be said for the Hatch Act which will be funded at $243.7 million in FY 2014. The Sustainable Agriculture Research and Education (SARE) program will also receive its highest-ever funding of $22.6 million.

2. Participated in **Farm Bill** stakeholder meetings and advocated for passage of the following provisions: A new nonprofit foundation, the **Foundation for Food and Agriculture Research (FFAR**), that is intended to complement--not replace--USDA's research, education, extension, and economics activities. FFAR is modeled after existing Foundations that were established to leverage private funding such as the Foundation for the National Institutes of Health and the National Fish and Wildlife Foundation. FFAR will have $200 million in mandatory funding as a match to solicit private donations for additional research on plant health; animal health; food safety and nutrition; renewable energy, natural resources and environment; agricultural and food security; technology; and agricultural economics and rural communities. FFAR will be led by a Board of Directors comprised of 15 members, of which 8 will be recommended by the National Science Foundation and 7 by industry. The new Farm Bill will also provide $80 million per year for the Specialty Crop Research Initiative (SCRI) and $20 million per year for the Organic Agriculture Research and Extension Initiative (OREI). These programs have been stranded without funding since 2012. The new funding levels are significant increases for both programs compared to the 2008 Farm Bill levels. In addition, the new funding that is authorized for SCRI is permanent funding.

   Unfortunately, there were a couple issues that didn't go the way we would have liked them too. One was a House provision that will require non-governmental organizations and private research institutions to provide a 100% match on all competitive research grants. However, the land grant universities are exempt from this matching funds requirement. The biggest disappointment is that Sen. Stabenow did not allow inclusion of the National Pollutant Discharge Elimination System (NPDES) fix language that was in the House version of the Farm Bill. There was strong bipartisan support for this language in both houses of Congress that would have clarified Congress's intent for the regulation of pesticides applied to or near water. As you know, all pesticide applications are regulated through FIFRA, especially applications to and near water. However in 2009, a three judge U.S. Circuit Court panel decided to muddy the waters and require a duplicative permitting process under the Clean Water Act NPDES permits. These permits' impose additional resource and liability burdens on small businesses, farms, municipalities, state agencies, and federal agencies, and exposes them to citizen law suits, all for no additional environmental benefits. The National and Regional Weed Science Societies have supported a legislative fix for this issue since the misguided Circuit Court ruling and will continue to support efforts to fix this going forward.

   Last but not least, I wanted to put in a reminder about the noxious weed control provision in the Commodity Title that has been in effect since the 2002 Farm Bill. In order for farmers to receive payments under the Commodity Title, the farmers shall agree -- "to effectively control noxious weeds and otherwise maintain the land in accordance with sound agricultural practices, as determined by the Secretary." The provision is part of the "Producer Agreements" section that also discusses conservation compliance for Highly Erodible Land and Wetland Conservation. The Farm Service Agency (FSA) and the Natural Resources Conservation Service (NRCS) have primary responsibility for enforcing these requirements. Having to "effectively control noxious weeds" and maintain conservation compliance is a pretty fair tradeoff, in my opinion, for the taxpayer subsidies that cover about 60 percent of the cost of each crop insurance premium.

3. Worked to get EPA to include **BMP's for managing high risk feedstocks**. The initial EPA rule approving *Arundo donax* and *Pennisetum purpureum* as biofuel feedstocks was delayed over a year and a half due to concerns WSSA and other natural areas stakeholders had. There are still many concerns about how EPA is implementing the rule. EPA is pushing a lot of the enforcement and 3rd party verification of the biofuel management plan permits on to APHIS. Neither agency has the money to conduct these reviews. EPA wrote the rule and APHIS opposed it, but it was still approved. Now APHIS is getting the short end of the stick.

4. Continued educating Federal agency and NGO stakeholders on **herbicide resistance management**, including coordination among WSSA, the Tri-Societies, Certified Crop Advisors, and the National Association of Independent Crop Consultants (NAICC). Watched for any legislation that would attempt to regulate herbicide resistance or restrict the interstate movement of herbicides due to resistance issues. A very successful herbicide resistance Stakeholder Conference was held in DC in Sept 2013. Recognition of the issues at highest levels of USDA (i.e. Deputy Secretary) and EPA (i.e. Director of OPP). Planning underway for 2nd Herbicide Resistance summit in Sept. 2014.

5. Generated support for the **Pesticide Safety Education Program (PSEP)** and have been participating in a national stakeholder group on behalf of WSSA. The mission of the stakeholder group is to find more permanent funding mechanisms at the federal and state level for PSEP. See www.psep.us

6. Generated support for Army Corps of Engineers (ACOE) **Aquatic Plant Control Research Program (APCRP)**. For the 3rd year in a row, funding was not requested by ACOE leadership. Support from Senator's Schumer (NY), Leahy (VT) and Cochran (MS) helped secure $4 million for FY 2014. We will likely be facing the same scenario again in FY 2015. Discussions were had with APMS leadership about transferring APCRP authority to USDA-ARS, but we decided the risks of completely losing the program was too great. APMS would like to see Lars Anderson's position refilled with USDA-ARS.

7. Submitted comments on behalf of WSSA regarding the Notices of Intent to prepare Environmental Impact Statements (EISs) for **2,4-D and dicamba resistant crops** under the National Environmental Policy Act (NEPA) issued by USDA-APHIS.

8. Coordinated and co-organized support for **National Invasive Species Awareness Week** (NISAW). However, due to the federal budget sequestration that happened two days before the start of NISAW, the Dept of Interior withdrew all National Invasive Species Council (NISC) funding for NISAW activities. However many state organized activities still occurred during the week as well as some events on Capitol Hill. Planning for 2015 is underway.

9. Stressed the importance to **USDA-ARS** leadership about hiring a new national program leader for weed science. I also coordinated with the National and Regional Weed Science

Society presidents' to help review and comment on USDA-ARS's 5 yr action plan for Crop Protection & Quarantine (NP304).

10. Submitted comments on behalf of WSSA to EPA for the FIFRA Science Advisory Panel (SAP) meeting regarding problem formulation phase **of risk assessment of pesticidal products based on RNA interference** (RNAi). *WSSA applauds EPA's decision to conduct this SAP and to evaluate the latest science regarding the risk assessment process for this exciting new technology. Early development of the regulatory approach needed to appropriately assess human health and ecological risks will facilitate the timely approvals and commercialization of this needed new technology. Our greatest concern about RNAi technology is that its regulation will exceed the risks, and it will be excessive to the point of stifling innovation. The potential of the topical application of dsRNA to, in effect, reverse resistance to many of our existing herbicides including glyphosate and members of the ALS inhibitor herbicide group is urgently needed to maintain our highly productive cropping systems and to stop the increase in soil erosion we are seeing due to the increased use of tillage to control herbicide resistant weeds. From a risk assessment perspective, we have a technology that offers the promise of being active only on a specific pest species. This fact should dramatically change the conduct of risk assessments that we have done for current GE crops. If an RNAi product is active only on the target pest which we'll be able to demonstrate through sequence alone, then there is no hazard other than to the target pest. Because risk is the joint probability of hazard and exposure, there is no risk because there is no hazard to non-target organisms or other environmental resources. It is our hope that these characteristics can lead to regulatory approaches that are reasonable and predictable. While much needs to be defined, fulfilling the promise of this technology for pest management may well be dependent on the time and cost of the regulatory structure for both the topical and biotechnology applications. We urge EPA to continue to rely on the many precedents that have been established to demonstrate the safety of nucleic acids to humans and the environment.*

11. **EPA SME, NIFA Fellow, and guidance on mechanism of action (MOA) labeling**.

12. **GMO Labeling-** WSSA is working on a draft educational statement opposing GMO labeling, similar to the positions taken by the American Association for the Advancement of Science, the American Phytopathological Association, and the Crop Science Society of America.

CAST: Communicating Credible Science in the Information Age. Phillip W. Stahlman*; Kansas State University, Hays, KS (053)

Today, fewer people in developed countries are involved or have accurate knowledge of production agriculture than any time in history. Many have grown suspicious of modern agriculture and food safety because of personal beliefs often influenced/reinforced by misinformation readily available on the internet and fervent opinions distributed through social media. More than 40 years ago public concern over some aspects of agriculture highlighted the need for a reputable source of accurate information on agricultural science and technology. A meeting of 16 agriculture-related scientific societies was convened by the National Research Council of the National Academy of Sciences to discuss how best to address that need. As a result, the Council for Agricultural Science and Technology (CAST) was founded in 1972 with a mission "*to assemble, interpret, and communicate credible science-based information regionally, nationally, and internationally to legislators, regulators, policymakers, the media, the private sector, and the general public.*" CAST's mission remains the same today as in 1972. CAST is a nonprofit organization composed of scientific societies and many individual, student, company, nonprofit and trade group, and associate society members. The organization is funded through membership dues, unrestricted financial gifts, and occasional grants. The Western Society of Weed Science has been a society member of CAST since July 24, 1978 – nearly 36 years.

Throughout its nearly 42-year history, CAST has fulfilled its mission by publishing factual, science-based reports on important topics related to agriculture, food sciences, and environmental issues written and reviewed by reputable subject-matter experts. They do this without financial compensation and are expected to uphold the principles of scholarship by balancing logic, facts, and truths from competing hypotheses and experimental results and set aside personal emotions and politics to allow unbiased analysis and interpretation of science. As a result, CAST has earned a strong reputation among regulators and policymakers and is viewed as a highly respected source of science-based information. The CAST brand, however, is not as well known or valued as it should be among the general public or, sadly, among many early and mid-career agriculture-related scientists. CAST has expanded the use of video and social media, and it continues to seek ways to increase connectivity with broader and younger audiences.

Funding issues, competing with the vast amount of information [misinformation] available on the Internet, and the ability to access that information via cell phones and other mobile devices are major challenges. Yet the need for credible science-based information is no less today than in the past and will only increase in the future. CAST has several publications in various stages of progress on important issues of agricultural and societal interests. A few examples of forthcoming publications of particular interest to WSWS members include *The Contributions of Pesticides to Pest Management in Meeting the Global Need for Food Production by 2050; The Potential Impacts of Mandatory Labeling for Genetically Engineered Food; Recruiting and Educating Graduate Students to Become Researchers and Leaders in Global Agricultural Studies*; and a series of papers on *The Need for Agricultural Innovation to Sustainably Feed the World by 2050.* Your membership is needed to help CAST fulfill its mission of educating an increasingly uninformed or misinformed public about agricultural science and technology.

Conserving the Air Force Academy Landscape through Integrated Noxious Weed Management. Brian Mihlbachler*; U.S. Fish and Wildlife Service, USAF Academy, CO (054)

The U.S. Air Force Academy campus is a National Historic Landmark well-known for its unique chapel and distinctive modernist architecture. Equally valued is the expansive open space - 67% of the installations 18,455 acres - which supports diverse habitats and wildlife, including several rare plants, animals, and natural communities. Unfortunately, the integrity and sustainability of these natural resources is threatened by the invasion of 22 noxious weeds aided by regional development, local land use, and multiple natural and man-made dispersal pathways. Intensive weed survey and monitoring efforts, conducted since 2002, has been critical for identifying and directing management priorities and strategies using an Integrated Weed Management approach. Key weeds targeted for control or suppression includes various knapweeds, thistles, spurges, and toadflax due to their wide distribution, abundance, and imminent threat to ecosystem integrity. Several less common species (e.g., Scotch thistle, Russian knapweed, houndstongue, Dames rocket, and tamarisk) are a high priority for eradication using early detection/rapid response protocols. The Air Force Academy utilizes a full array of weed control techniques, which is imperative for managing a landscape that supports important and sensitive biological diversity, and has tremendous public interest and visibility. Biological weed control efforts and trends observed from long-term (9 years) weed monitoring will be discussed in presentations from Texas A&M AgriLife Research and Colorado Natural Heritage Program scientists.

Nine Years of Weed Monitoring at the Air Force Academy: Integrating Results Into Management Decisions. Renee Rondeau*, Amy Lavender, David Anderson; Colorado State University, Fort Collins, CO (055)

The Colorado Natural Heritage Program has been mapping and monitoring weeds at the Air Force Academy since 2002. Every 5 years we map weeds throughout the Academy and every year we monitor a select set of weeds. The number of weed species and mapped areas continue to go up with each mapping year: 14 species in 2002, 17 species in 2007, and 22 species in 2012. Annually, we monitor 15 species utilizing mapping and plot data. The following species are mapped each year, collecting area occupied, density, and cover: Bouncingbet, Common St. Johnswort, Dalmatian toadflax, Houndstongue, Mrytle spurge, Russian knapweed, Scotch thistle, Tamarisk, Tartarian honeysuckle, and Yellow spring bedstraw. The Air Force Academy has successfully managed to either significantly decrease or at least maintain the abundance of the above weeds by pulling, mowing, or herbicide treatment. In addition to mapping the uncommon species we monitor the more common and widespread species that are being treated by biocontrol or herbicide treatment. We use the same methods as Texas A & M University to collect plot data, using up to 60-0.5 x 0.5 m quadrats situated along transects. We collect frequency, density, and canopy cover data. The following species are monitored with plots: Canada thistle, diffuse knapweed, spotted knapweed, whitetop, leafy spurge, and musk thistle. We present 2012-2013 data for plots that were recently established. The Air Force Academy utilizes the results of the annual weed monitoring data to determine where, how, and when weed management will take place. Early detection and rapid response has shown to be the most effective and least costly action for controlling weeds.

Biological Control of Noxious Weeds at the Air Force Academy: Successes and Management Insights 2001-2013. Jerry Michels*, Erin Parks; Texas A&M University, Amarillo, TX (056)

A program to implement biological control of noxious weeds at the Air Force academy started in 2001. The program is complimentary to other aspects of noxious weed management at the Academy, and is directed at controlling weeds in habitats sensitive to herbicide treatments. In these twelve years, biological control has had varying levels of success depending on the specific weeds involved. Knapweeds, leafy spurge and musk thistle have been relatively easy to control because multiple biocontrol agents are available that act in conjunction with each other to produce a synergizing effect. Canada thistle, field bindweed, and yellow toadflax have proven more difficult to control because only one biocontrol agent is available, the available agents are not well adapted to the climate at the area, or post-release management is difficult. Still other noxious weeds are not candidates for a biocontrol program because they exist in small patches more conducive to spot herbicide treatment or no biocontrol agents exist. Although the ecology of the weeds and their respective biocontrol agents and climate are of paramount importance, other factors such as coordination of control strategies and management priorities also play a role in the success of the noxious weed control program. Understanding the interplay of weed and biocontrol agent ecology, the impact of climatic variability, and management priorities is important to successfully integrating a weed management program.

PROJECT 1: WEEDS OF RANGE AND NATURAL AREAS

Integrating Herbicides and Revegetation to Restore Rangeland Infested with Spotted Knapweed (*Centaurea stoebe*) and Downy Brome (*Bromus tectorum*). Jane Mangold*[1], Noelle Orloff[1], Hilary Parkinson[1], Mary Halstvedt[2]; [1]Montana State University, Bozeman, MT, [2]Dow AgroSciences, Billings, MT (057)

Some rangeland plant communities previously comprised of native grasses and forbs are now co-dominated by a complex of invasive forbs and annual grasses. Management often focuses on controlling the invasive forb(s) with little regard to annual grasses. If remnant native perennial grasses are no longer present to re-occupy the site following invasive forb control, annualgrasses may proliferate. We applied a variety of combinations of herbicides that would control the invasive forb spotted knapweed (*Centaurea stoebe*) and the annual grass downy brome (*Bromus tectorum*) followed by re-seeding with desirable grasses in an attempt to restore degraded rangeland. We applied eight herbicide treatments and six re-seeding treatments in late summer and fall 2009 at two sites in western Montana. Four years post-treatment, we sampled density and biomass of established seeded grasses and cover of spotted knapweed and downy brome. Of the seeded grasses, tall wheatgrass (*Agropyron elongatum*) and bluebunch wheatgrass (*Agropyron spicatum*) were established at densities of about 1.1 and 1 plant/m^2, respectively, averaged across all herbicide treatments, but herbicide treatment did not influence establishment. Herbicide and seeding interacted to influence spotted knapweed cover; applying aminopyralid and revegetating with tall or bluebunch wheatgrass reduced spotted knapweed to 0% cover, while non-seeded plots had about 5% spotted knapweed cover. Downy brome cover four years after treatment was only influenced by herbicide treatment. Aminopyralid reduced downy brome cover to about 1% compared to the non-sprayed treatment at about 4%. Our data support the integration of herbicides and revegetation to decrease spotted knapweed cover, but downy brome cover appears to be more variable and unpredictable.

Interactive Fire and Grazing to Manage Rangeland Invaded by Exotic C3 Graminoids. John D. Scasta*[1], David M. Engle[1], Diane Debinski[2], Rebecca McCulley[3]; [1]Oklahoma State University, Stillwater, OK,[2]Iowa State University, Ames, IA, [3]University of Kentucky, Lexington, KY (058)

Tall fescue (*Schedonorus arundinaceus*), an exotic C3 grass, has become invasive in the mesic Great Plains. *S. arundinaceus* can host a fungal endophyte that improves plant persistence but also produces alkaloids toxic to many animals. In cattle, fescue toxicosis involves vasoconstriction, elevated body temperatures and respiration rates. Fire-driven grazing or pyric-herbivory is a technique that can slow the spread of some invasive plants by increasing herbivory on unpalatable species. For *S. arundinaceus*, pyric-herbivory may increase animal exposure to toxic alkaloids if herbivory increases, endophyte presence increases, or alkaloid production *in planta* increases. In 2012 and 2013, we examined whether pyric-herbivory increases herbivory of *S. arundinaceus*, reduces *S. arundinaceus* canopy cover, or alters 1) endophyte infection frequency, 2) alkaloid concentrations, or 3) cattle toxicosis. Herbivory of *S. arundinaceus* was 2x to 3x higher in the recently burned patch, compared to unburned patches or pastures that were burned completely or not burned at all. Canopy cover was not reduced, but ungrazed tillers were shortest in the recently burned patches. Pastures managed with pyric-herbivory had lower overall endophyte infection compared to traditionally managed pastures in a mixed effects model accounting for inter-annual climate variability. Whenever pastures had fire, either patchy or complete, there was no detectable ergovaline > 100 ppb in any herd, but when pastures had no fire, ergovaline > 100 ppb was detected in 50% of the herds. Patch-burn grazing did not reduce *S. arundinaceus* dominance, but may overcome the grazing deterrence of the fungal endophyte and mitigate animal toxicosis.

Paper (059) was withdrawn

Investigating Russian Knapweed and Downy Brome Management Strategies at Dinosaur National Monument. Trevor M. Peterson*, Corey V. Ransom, Heather Elwood; Utah State University, Logan, UT (060)

Russian knapweed and downy brome trials were conducted at Dinosaur National Monument, located on the Colorado and Utah border. Russian knapweed trials were established in spring 2009 and 2010. A split-plot design was used with spring grazing verses un-grazed as the whole plot and subplot treatments consisted of increasing rates of fall applied aminopyralid at 0, 53, 70, 88, and 105 g ai haâ»¹. Downy brome trials were established April 2010 at Josie's Ranch and Echo Park. Also arranged in a split-plot design, spring whole plot treatments included: untreated, mowing, and glyphosate at 193 g ai haâ»¹; fall subplot treatments were: untreated, imazapic at 70, 105, 140, 175, and 210 g ai ha â»¹, sulfosulfuron at 70 g ai ha â»¹, and rimsulfuron at 53 g ai haâ»¹. Additional glyphosate at 193 g ai haâ»¹ was applied in spring 2013 over glyphosate whole plots. For all trials, plots were replicated four times. Data collected included visual control, vegetative cover, and biomass. For Russian knapweed trials, only herbicide main effects were significant, with all rates of aminopyralid decreasing Russian knapweed cover and biomass and a corresponding increase in desirable grass cover and generally increased grass biomass. In the downy brome trials, spring glyphosate on whole plots significantly reduced downy brome cover. All herbicide treatments significantly reduced downy brome cover at Echo Park, while only the highest rate of imazapic, sulfosulfuron, and rimsulfuron reduced downy brome cover at Josie's Ranch. At Josie's Ranch treatments controlling downy brome increased desirable grass cover.

Managing Ventenata dubia in Perennial Grass Systems of the Pacific Northwest. Timothy Prather*[1], John Wallace[2], Andrew Mackey[1], George Newcombe[1], Philip Watson[1]; [1]University of Idaho, Moscow, ID, [2]Penn State University, State College, PA (061)

Vententata dubia, also called ventenata or North Africa grass, is not new to Idaho but recently has dominated annual canyon grasslands formerly dominated by downy brome and it now dominates in perennial grass systems that include pasture, hay and Conservation Reserve Program grasslands. Damages to forage production, including hay and pasture in Northern Idaho and Eastern Washington are estimated at $22 million each year. Basic biology information and management strategies are lacking for North Africa grass and led us to study seed bank longevity, plant development modeling using degree days, interactions that allow it to dominate perennial grasses and management strategies. North Africa grass is an annual that usually emerges in the fall after we have 2 cm of precipitation and soil temperatures above 7 C. Seed longevity appears to be less than 4 years. Plants develop along a degree day development schedule that appears to be similar regardless of the system it is growing in (CRP, hay, pasture or rangeland). North Africa grass may dominate, in part, because of interactions with litter and changes to soil fertility but we also have discovered North Africa grass is associated with fungi that can damage other plants but don't damage North Africa grass. Timothy hay is more competitive when fertilized properly and cutting height is no shorter than 10 cm. North Africa grass is high in silica and so its litter does not degrade and the litter protects the seedlings. We found that burning in the fall or spring reduces the number of seedlings that survive cold temperatures. We have found herbicides like imazapic, sulfosulfuron, flufenacet + metributzin, and propoxycarbazone all control North Africa grass. Fortunately we have options for control but North Africa grass has become a significant challenge and continues to expand to new areas.

Effects of Sequential Herbicide Applications and Grazing Exclusion on Downy Brome and Native Rangeland Vegetation. Shayla A. Burnett*, Brian A. Mealor; University of Wyoming, Laramie, WY (062)

Downy brome is one of the most significant invasive plants in North America. Because eradication may not be feasible, it may be desirable to manage downy brome in low-density stands below the 'impact' stage of invasion. Little work has investigated managing such stands by single or sequential herbicide applications. In Wyoming's Thunder Basin Grassland, we chose 7 sites to inset 3 randomized complete blocks. Five sites were treated previously with imazapic in different years (2006-2010). Two sites – one dominated by needle-and-thread and one by blue grama – were treated for the first time in 2011 and included a simulated grazing treatment combined with the herbicide treatments. Herbicide treatments included no herbicide, imazapic (70 and 105 g ai ha^{-1}), propoxycarbazone sodium (59 g ai ha^{-1}), rimsulfuron (52.5 g ai ha^{-1}), and tebuthiuron (170 g ai ha^{-1}) with aminopyralid (92 g ai ha^{-1}) applied in a total spray solution of 140 L ha^{-1} prior to downy brome emergence in fall 2011. We evaluated the vegetation response – including cover, biomass production, and seedbank – in summer 2012 and 2013. Defoliation had minimal to no effect on the plant community ($p>0.05$). All herbicide treatments reduced downy brome canopy cover ($p=0.0284$) and biomass production ($p=0.0005$) at the needle-and-thread site in 2012 but had little effect on vegetation cover at the other sites in either year ($p>0.05$). The germinable seedbank was largely unaffected by herbicide. Although treated twice with herbicides effective at controlling downy brome, the native plant community was minimally impacted.

Buffelgrass Control with Glyphosate, Clethodim, Imazapic, and Imazapyr. Travis M. Bean*, William B. McCloskey; University of Arizona, Tucson, AZ (063)

Buffelgrass is a perennial C_4 bunchgrass that is invasive in subtropical regions worldwide. It can compete with and displace native vegetation, often resulting in ecosystem replacement and altered fire regimes. We conducted a series of replicated field experiments from 2010 to 2013 at two sites near Tucson, AZ to investigate herbicides and herbicide mixtures, application rates, and application timing effects for control of buffelgrass. We evaluated the effects of different rates of two herbicides (imazapic and clethodim), alone or in combination with different rates of glyphosate, for pre- (imazapic only) and postemergence control of buffelgrass. We also evaluated growing- (summer) and dormant- (winter) season application of imazapyr for pre- and postemergence control of buffelgrass. We used broadcast applications using CO_2 sprayers at known pressures, speeds, and carrier rates to ensure precise and accurate application rates. Our results indicate that when applied alone, glyphosate rates of 2.52 kg ha^{-1}(2.5 lb ae ac^{-1}) are needed to kill mature plants in a single application. Lower rates of glyphosate were effective when combined with imazapic. Imazapic did not kill mature buffelgrass plants even at the highest label rate, although this rate (210 g ae ha^{-1} [3 oz ae ac^{-1}]) did suppress shoot growth at 36 MAT (months after treatment). Clethodim did not have any effect on buffelgrass response variables tested, even at the highest label rate. At one site only, imazapyr was effective at killing mature buffelgrass plants 6 MAT when applied during the dormant season using a 0.566 kg ha^{-1} (0.56 lb ae ac^{-1}) rate, or 12 MAT when applied during the growing season using a 1.12 kg ha^{-1} (1.1 lb ae ac^{-1}) rate. All rates of imazapyr provided preemergence control of buffelgrass 6 and 12 MAT.

Beyond Presence-Absence: Prioritizing Wyoming's Downy Brome Infestations. Cara E. Noseworthy*, Brian A. Mealor; University of Wyoming, Laramie, WY (064)

Downy brome (*Bromus tectorum* L.) is an invasive winter annual grass prevalent enough in the state of Wyoming to warrant concern from public and private land managers. It is one of many invasive species in the state, which means prioritizing to ensure the most efficient use of time and resources is important. Current distribution models do not provide enough information beyond presence/absence for effective prioritization. This project has three objectives: 1) to synthesize distribution data from around Wyoming, 2) to develop a distribution model, and 3) to develop a spatially-explicit prioritization model based on invasion status, estimated recovery potential, and potential as wildlife habitat. We developed a rapid assessment protocol to classify survey points into invasion levels based on measures of downy brome, natives and other qualitative measures (disturbance, other invasive grasses, etc.). Over 12,000 sites have been assessed with around 90% of the sites classified as downy brome free. Future surveys will target areas of downy brome dominance to increase understanding of invasion and balance the data. We have developed a preliminary distribution prediction model of approximately 80% accuracy which will eventually incorporate data from summer 2014 and undergo a more extensive model validation process. This model will be used to identify areas of high risk for downy brome dominance and, in conjunction with habitat indicators, to prioritize areas for management action. The final goal is to provide a tool to land managers that will be the first step in a statewide cooperative approach to managing downy brome.

Best Management Practices for Eight Invasive Plants in Arizona. John H. Brock*, Professor Emeritus, Arizona State University Polytechnic, Mesa, AZ (065)

Invasive plants cause economic or environmental harm or harm to human health. Information is presented for best management practices to provide control of invasive plants common in the Southwestern United States. Invasive plants selected for this presentation include: *Acroptilon repens* (L.) DC., *Alhagi maurorum* Medik., *Bromus rubens* L., *Centaurea melitensis* L., *C. solstitialis* L., *Elaeagnus angustifolia* L., *Pennisetum cilare* (L.) Link., *Salsola kali* L., and *Tamarix ramosissima* Ledeb. Best management practices rely on four categories of vegetation management: (1). Cultural, (2). Prescribed fire, (3). Biological agents and (4). Chemicals. These treatments can be applied alone or in a sequence depending on the management goals. In some cases, herbicide combinations used increase efficacy and/or lower the cost of the treatment. While, integrated pest management is practiced for invasive plants, herbicides tend to be the most practical or economical practice for controlling invasive plants in the Southwestern USA.

The Potential for Downy Brome Control with a Fungal Pathogen. Krista A. Ehlert*[1], Fabian Menalled[2], Jane Mangold[2], Zachariah Miller[2], Alan Dyer[2]; [1]Montana State University - Bozeman, Bozeman, MT,[2]Montana State University, Bozeman, MT (066)

Herbicide application is the traditional management approach for downy brome. While herbicides do not affect downy brome's seedbank, a soil-borne fungal pathogen *Pyrenophora semeniperda* causes seed death and reduced seedling vigor. In addition to downy brome, we investigated *P. semeniperda*'s impact on five crop, five non-native forage/pasture, and five native rangeland species. In a greenhouse, we established a randomized complete block design with eight blocks. Treatments were a) inoculated and b) non-inoculated (control). Seedling emergence and survivorship were recorded weekly, and aboveground biomass was harvested, dried, and weighed four weeks after seeding. Results suggest that inoculation affects species' emergence ($P < 0.0001$) and biomass ($P = 0.0108$). Four of the five rangeland species were negatively affected by inoculation, which resulted in a 20-80% reduction in emergence relative to the non-inoculated treatment. Further, inoculation resulted in 25-30% and 10-35% reduced emergence for three forage and two crop species, respectively. Inoculation reduced downy brome emergence by 40%; however, its biomass was unaffected. There was little effect of inoculation on non-target plant biomass, with the exception of one crop and two forage/pasture species. These results indicate that *P. semeniperda* is not a silver bullet for downy brome but has potential as an additional tool for management. Integrated management with other tools such as herbicides and fungicides can provide a two-pronged approach that effectively targets both downy brome's seedbank and its seedlings.

A Computer-Based Tool for Prioritizing Spatial and Species Targets for Inventory. Heather Elwood*, Corey V. Ransom; Utah State University, Logan, UT (067)

In 2003, the National Wildlife Refuge System released the National Strategy for Management of Invasive Species with one of the objectives being to "increase and focus on invasive species research, surveys, mapping, and monitoring efforts". In an effort to meet this objective, a pilot project in cooperation with Utah State University was initiated at four refuges across the country to evaluate the similarities and differences in invasive plant inventory objectives and methods among a variety of refuge environments. Building off what was learned from the pilot project, the U.S. Fish and Wildlife Service National Wildlife Refuge System and USU have developed a computer-based tool for prioritizing species and spatial targets for inventory.

Like other public land management agencies, refuges face the challenge of managing large acreages with numerous species and limited resources and staff. Although the importance of inventory and monitoring are understood, they are often overlooked due to the resources and time required; and many species that could be easily managed in the early stages of invasion are left untreated because they were unnoticed.

The prioritization tool developed by USU and the USFWS provides a framework for land managers to assess and determine the status of priority invasive plants and where to search for them. Using both a quantitative and qualitative approach, the tool asks managers to consider factors such as disturbance, density of vector pathways, and the ecological state of management units as well as known or potential infestation status of specific target species. The results are a prioritized list of species targets for inventory and a prioritized list of spatial targets for inventory. A combined list of species prioritized on a spatial basis is also generated.

Does Downy Brome Litter Reduce Herbicide Efficacy? Kallie C. Kessler*[1], Scott J. Nissen[2], George Beck[2]; [1]Colorado State University, Ft. Collins, CO, [2]Colorado State University, Fort Collins, CO (068)

A field study conducted in 2012 indicated an appropriately timed prescribed burn followed by soil residual herbicides significantly decreased downy brome biomass when compared to herbicide applications alone. Removal of the litter layer (approx. 341 g/m^2) with fire may have contributed to the increase in herbicide efficacy. To evaluate the impact of litter on herbicide performance, imazapic and tebuthiuron sorption to litter was evaluated. Imazapic (105 g ai/ha) and tebuthiuron (420 g ai/ha) were applied to 341 g/m^2 of field collected litter. After seven days, simulated rainfall events of 5 mm and 15 mm were conducted. At 5 mm of rainfall, 61±3.2% of adsorbed imazapic and 51±2.3% of adsorbed tebuthiuron was removed from the litter. When rainfall was increased to 15 mm, 73±2.3% of adsorbed imazapic and 66±2.6% of adsorbed tebuthiuron was removed from the litter. After 15 mm of simulated rainfall, 27±1.9% of imazapic and 34±0.8% of tebuthiuron remained sorbed to the litter. The initial litter layer (341 g/m^2) intercepted 72±0.8% of the spray solution; however, when litter amounts were reduced to 227 g/m^2 and 113 g/m^2 spray interception decreased to 57±0.1% and 38±0.4%, respectively. In all analyzed combinations of litter and precipitation, tebuthiuron remained sorbed to litter at higher percentages than imazapic. This study indicates that litter amount and precipitation may impact the bioavailability of both herbicides under field conditions.

Paper (091) was withdrawn

Cut Stump Russian Olive (*Elaeagnus angustifolia*) Control in the Northern Front Range of Colorado. Thomas J. Getts*, Phil Westra; Colorado State University, Fort Collins, CO (092)

Russian olive was introduced in the early 1900's to North America as a soil stabilizing/windbreak species. It has successfully established in western riparian areas and is now considered a noxious species in many western states. Cut stump studies were implemented in the fall of 2010 to determine if aminocyclopyrachlor offered comparable control to imazapyr, triclopyr, and glyphosate. These treatments were replicated 39 times across three sites along Colorado's Front Range. Herbicides were mixed in JLB Basal Bark oil, and applied within 5 minutes after felling trees. Aminocyclopyrachlor was applied at 9.5 g ai/tree, imazapyr 4.0 g ai/tree, triclopyr 19.5 g ai/tree, and glyphosate 64.5 g ai/tree. Every six months for thirty months, trees were monitored to assess mortality, and radius of inhibition (ROI-radius of bare soil surrounding stump). For all herbicide treatments 6, 18, and 30 months after treatment, the percent of living trees was significantly lower than the untreated check (pvalue<.05), but there were no differences between treatments (pvalue>.05). Thirty months after treatment 5%, 8%, 26% and 30% of trees were alive for glyphosate, aminocyclopyrachlor, imazapyr, and triclopyr. ROI decreased over time for all herbicide treatments. Thirty months after treatment the average ROI was 4 cm, 8 cm, 13 cm, and 26 cm, for glyphosate, triclopyr, imazapyr, and aminocyclopyrachlor. For the percentage of living trees, aminocyclopyrachlor was comparable to other herbicide treatments (pvalue>.05). However, when aminocyclopyrachlor was compared to other herbicide treatments, it had the largest ROI 30 months after treatment (pvalue<.05).

Rubber Rabbitbrush Control Using a Combination of Mowing and Various Herbicide Treatments. Chad Reid[1], Dean Windward[2], Randall Violett*[2]; [1]Utah State University Extension, Cedar City, UT,[2]Southern Utah University, Cedar City, UT (093)

Rubber rabbitbrush *(Ericameria nauseosa)* is a very prolific seed producer and can be extremely invasive, particularly in disturbed areas such as abandoned homesteads or rangeland seedings. Management of rabbitbrush is difficult because it is deep rooted and sprouts vigorously after disturbance such as fire or mechanical treatments. Many treatments and combinations of treatments have been tried with little success or with highly variable results. As illustrated by three years of work in small plot trials showing results from 0 to 90% control with fall applications of picloram. Additional work of tank mixing picloram with dicamba + 2, 4-D resulted in more consistent control of 70 to 80% when applied in the fall. The recent development of aminocyclopyrachlor + metsulfuron-methyl, warranted a three year comparison study, conducted at the SUU Valley Farm in Cedar City, Utah. The results of 80 to 96% control was established by applying 336 g ai/ha of aminocyclopyrachlor + metsulfuron-methyl, as a fall treatment.

Integrated Management of Tall Buttercup (*Ranunculus acris*) in Montana Meadows. Hally K. Berg*, Jane Mangold; Montana State University, Bozeman, MT (094)

Tall buttercup, an invasive perennial forb found in moist fields and sub-irrigated meadows, was listed as a noxious weed in Montana in 2003. However, little is known about how to effectively control the species. To develop an integrated management system for tall buttercup, two study sites were established in 2012 in sub-irrigated hay meadows in southwestern Montana. Treatments were applied in a split-plot design with four replications per site. Four herbicide treatments were applied at the whole-plot level: non-treated, aminocylopyrachlor (11.7 kg a.i. ha^{-1}), aminopyralid (17.2 kg a.i. ha^{-1}) and dicamba (98.1 kg a.i. ha^{-1}). Split-plots consisted of mowing (non-mowed, mowed) and fertilization (non-fertilized, fertilized at 11 kg N ha^{-1}). Biomass was sampled by functional group (perennial grass, grass-like, exotic/native forbs, and tall buttercup) in 2012 and 2013. Data were analyzed using split-plot analysis of variance. Across years at site one, herbicides ($P<0.001$) and mowing ($P=0.018$) influenced tall buttercup. However, decreases in tall buttercup only occurred in 2013. Relative to the control, aminocyclopyrachlor and aminopyralid reduced tall buttercup by 15 g m^{-2}; mowing decreased buttercup by 10 g m^{-2}. At site two, tall buttercup was affected by herbicides ($P<0.001$). Aminocyclopyrachlor and aminopyralid decreased tall buttercup by 31 g m^{-2}. Herbicide influenced perennial grasses across years ($P<0.001$) and sites ($P<0.001$). Aminocyclopyrachlor reduced perennial grass at site one by 88 g m^{-2} and by 140 g m^{-2} at site two. At site two, herbicides influenced grass-like ($P=0.001$) and exotic forbs ($P<0.001$). Aminopyralid and aminocyclopyrachlor reduced exotic forbs, while aminocyclopyrachlor increased grass-like species.

Do Hybrids of Yellow Starthistle and Meadow Knapweed Backcross with Parent Species?
John J. Miskella, Andrew G. Hulting*, Carol Mallory-Smith; Oregon State University, Corvallis, OR (095)

Hybridization between meadow knapweed and yellow starthistle was reported in the Rogue River Valley, OR and confirmed through comparison of putative hybrids collected from the field and hybrids produced through controlled crosses between the parent species. Controlled crosses were then conducted between hybrids and the parent species to test for the potential for backcrossing. The crosses were made in greenhouses using hand-pollination methods. Genome size, measured by flow cytometry, and four morphological characters, including number of bracts per head, number of appendages per bract, length of apical appendage, and number of lobes per rosette leaf, were measured for the backcross progeny, the parent species, and the hybrids. The groups were compared to determine if the progeny was the result of backcrossing or self-pollination. Nineteen plants were produced from hybrid maternal parents pollinated by meadow knapweed and appear to be backcrosses. One plant was produced from a hybrid maternal parent pollinated by yellow starthistle and appears to be a self-pollinated hybrid. Thirty-seven progeny were produced from meadow knapweed maternal parents and all appear to be self-pollinated. Sixty-seven of the 75 total progeny from yellow starthistle maternal were self-pollinated. Eight had genome sizes indicating they were likely backcrosses. Five of these putative backcrosses died, two had morphological characters indicating they are likely backcrosses, and for one, it is unclear whether it is self-pollinated or backcrossed. The most important result of this study is that hybrids produced twenty viable offspring from either cross- or self-pollination. Backcrossing could lead to introgression between meadow knapweed and yellow starthistle. Traits which could increase invasiveness could be transferred between the species. These hybrids should be aggressively managed in the field where they are known to occur.

Quinclorac and Aminocyclopyrachlor Movement in the Sandy Soils of the Sheyenne National Grassland. Jason W. Adams*[1], Rodney G. Lym[2]; [1]North Dakota State University, FARGO, ND, [2]North Dakota State University, Fargo, ND (096)

The Sheyenne National Grassland (SNG) covers 28,400 ha of tall and mixed grass prairies, with sandy soils and a shallow water table. Approximately half of the SNG has been invaded by leafy spurge (*Euphorbia esula* L.) which continues to spread in part because U.S. Forest Service regulations have restricted herbicide use to 2,4-D. Quinclorac and aminocyclopyrachlor will control leafy spurge and are being considered for use at the SNG. However, the leaching potential of these herbicides in the sandy soils of the SNG is unknown. Soil columns were used to replicate field conditions of five predominant ecological sites at the SNG. Leaching potential was evaluated for aminocyclopyrachlor at 140 g ha^{-1} and quinclorac at 420 g ha^{-1} over two precipitation events; the annual average of 51 cm applied over 9 wk and the heaviest recorded rain event of 15 cm over 48 h. Herbicide concentration was estimated using sunflower or soybean bioassays for quinclorac and aminocyclopyrachlor, respectively. Quinclorac did not leach past 55 cm in four of the five soils after either precipitation event and was less after 51 cm in 9 wk compared to 15 cm applied in 48 h. Quinclorac leaching decreased as soil clay and organic matter increased. Aminocyclopyrachlor leaching was greater than quinclorac and moved through all soil types following both precipitation events. Quinclorac may be suitable for use at the SNG to control leafy spurge; however, due to the high leaching potential aminocyclopyrachlor will not be recommended.

Measuring Herbicide Translocation in Bohemian Knotweed (*Polygonum x bohemicum*) Using a Rhizome Bioassay. Timothy W. Miller*[1], Cathy Lucero[2], Carl R. Libbey[3]; [1]Research and Extension Scientist, Mount Vernon, WA, [2]Clallam County Noxious Weed Coordinator, Port Angeles, WA, [3]Research Tchnologist, Mount Vernon, WA (097)

Bohemian knotweed is a noxious perennial weed found in higher rainfall areas throughout the Pacific Northwest and elsewhere. A trial was designed to test the ability of foliar-applied glyphosate and imazapyr to translocate into and inhibit shoot growth from excised rhizomes. The trial was conducted at the WSU Northwestern Washington Research and Extension Center near Mount Vernon during 2010-11 and repeated in 2012-13. Bohemian knotweed shoots were dug in the summer, grown in greenhouse pots for 6 weeks, then single plants transplanted in September into wading pools filled with potting soil and buried up to their rims in the field. Herbicides (1.2 g ai glyphosate and 0.24 g ai imazapyr, equivalent to 2.5 ml Rodeo® and 1 ml Habitat®) were mixed with 0.25% nonionic surfactant and water to make 100 ml of solution and applied to each knotweed plant the following year when plants were beginning to bloom (late August) or post-bloom in autumn (mid October). Plants were dug at 24 or 72 hours after treatment (HAT) and rhizomes placed in flats of potting soil in the greenhouse for 5 weeks, after which shoots and rhizomes were counted and dry biomass determined. Rhizome measurements, representing pre-treatment Bohemian knotweed growth, did not differ among treatments or from nontreated plants, but did differ by year. Average rhizome number per plant was 7.9 in 2011, measuring 349 cm long and weighing 42.3 g; in 2013, number, length, and biomass was 4.5, 145 cm, and 16.2 g. Glyphosate reduced shoot number 66 and 53% in 2011 and 2013, respectively, while imazapyr reduced shoot number 96 and 87%, respectively. Shoot biomass was reduced 97% by imazapyr in both years of the trial, while reductions with glyphosate were 90 to 93% depending on year.

While herbicides were about 8 times more effective at suppressing shoot growth when applied in the autumn than at bloom in 2011, application timing made no difference in 2013. Nontreated knotweed rhizomes also produced 66 to 83% fewer shoots when dug in autumn than when dug from blooming plants. There was no significant difference between translocation rates of the two herbicides, although shoot biomass tended to be lower if allowed to translocate for 72 hours rather than 24 hours.

Evaluating Weed Management Strategies for Improving Reclamation. Beth Fowers*, Brian A. Mealor; University of Wyoming, Laramie, WY (098)

As part of the process of energy extraction, soils are scraped from sites to access mineral deposits or to create level surfaces for drilling or mining activities. Reclamation after disturbance of soils and vegetation associated with energy extraction is critical for ecosystem function and is required by law. Weedy annual species often dominate reclamation sites for the short-term, competing for resources with newly-seeded desirable vegetation. Our objectives were to: 1) evaluate herbicide effects on weedy and desirable species, 2) determine the effect of treatment timing (herbicide and seeding) on reclamation success, and 3) evaluate the performance of different species and mixes. Fifteen herbicide treatments and ten seed mixes were applied in a split-plot design to three sites in Wyoming to evaluate effectiveness of different reclamation practices. Seeding treatments were applied at two timings (fall, spring) across herbicide treatments to investigate establishment rates of specific species under different seeding times. Second-year data from one site on weed control and seeded species establishment from cover and percent stand observations from mid-summer 2013 are presented. Herbicides, specifically those including aminocyclopyrachlor, reduced annual weedy forb cover ($p<0.0001$). Undesirable annual grasses were reduced by herbicides ($p=0.0002$). The most effective were rimsulfuron and imazapic. Establishment differences were observed among seeded species ($p<0.0001$). Seeded wheatgrass and wildrye species established best. Higher establishment occurred at a site where annual grass competition was reduced with spring seeding. Evaluation will continue for a third year.

Reducing the Nascent Patch Network of Miconia (Miconia calvescens DC) with an Accelerated Intervention Strategy Utilizing Herbicide Ballistic Technology (HBT). James Leary*[1], Brooke Mahken[2], Jeremy Gooding[3], Adam Radford[2], Teya Penniman[2], Linda Cox[4], David Duffy[4]; [1]University of Hawaii at Manoa, Kula, HI, [2]Maui Invasive Species Committee, Piiholo, HI, [3]Pacific Islands Exotic Plant Management, Makawao, HI, [4]University of Hawaii at Manoa, Honolulu, HI (128

The miconia invasion of the East Maui Watershed (EMW) started from a single introduction over 40 yr ago, establishing a nascent patch network spread across 20,000 ha (50,000 acres). We describe the spatial and temporal aspects of an accelerated intervention strategy for reducing target densities by implementing Herbicide Ballistic Technology (HBT) from a Hughes 500D helicopter platform. In a 2-yr period, 17 search and intervention missions were conducted covering a total net area of 3,888 ha, eliminating 7,463 miconia targets. Search effort (min/ha) and herbicide use rate (projectile consumption) showed positive linear dependence on target densities encountered in an operation. Forty-eight percent of the total net area (1850 ha) was searched with only 4% of the total operational flight time (OFT), focusing a majority of the OFT conducting interventions within known target locations. Over The course of these sequential interventions, target density reduction of the entire patch network has been fit to an exponential decay function that allows for projecting resource needs (e.g., flight time and projectile inventory) towards accomplishing effective containment goals. This strategy increased the frequency of interventions by 38% relative to previous recorded efforts dating back 2005-2011, resulting in a 168% increase in target elimination. Less than 16% of the total net area (599 ha) contained miconia treated with HBT. Furthermore, 89% of that treated area received <1% the maximum allowable herbicide use rate. This is a highlight to the surgical approach of an HBT (directed) treatment application. This accelerated intervention strategy was an adaptive process focusing on known target locations that compensated for imperfect detection with frequent overlapping interventions and always generated new intelligence containing explicit spatial and temporal relevance to the next intervention.

Forage Yield Following Big Sagebrush Control in Northeastern Arizona. John H. Brock* Benita Litson[2], Bennie Litson[3], [1] Professor Emeritus, Arizona State University Polytechnic, Mesa, AZ, [2]Director, Land Grant Office, Dine College, Tsaile, AZ, [3]Litson Ranch Manager, Tsaile, AZ (129)

Big sagebrush (*Artemisia tridentata* Nutt.) has increased in dominance on western rangelands in the absence of periodic fires and to past livestock grazing practices. Information in this abstract covers two studies. One study is a ranch application of herbicide and the other study is a small plots herbicide test. The Litson family of Chinle/Tsaile, Arizona began initiating a rangeland management plan about 10 years ago. In that plan, dense stands of big sagebrush were targeted for control. The control technique chosen was to broadcast tebuthiuron pellets at 0.5 kg/ha. Summer grazing has been deferred in this pasture since treatments began in December of 2010. After three growing seasons, forage response to the control of big sagebrush was estimated. Big sagebrush canopy reduction from the tebuthiuron herbicide application was 84 percent. In October 2013, forage yield was approximately three times more compared to untreated areas in the same pasture. A test of various herbicides combined with aminocyclopyrachor was carried out on a set of small trial plots in the same pasture. In the herbicide trial, two years after treatment, forage production increased by a similar amount. Reduction in live canopy and mortality of big sagebrush ranged from nearly complete control to marginal from aminocyclopyrachor and companion herbicides. Even with the precipitation being below normal in the years following treatment, beneficial summer rainfall and big sagebrush control produced increases in forage production.

Spring or Fall Aminopyralid Effects on Native Plant Communities in Northwest Colorado. George Beck*[1], James R. Sebastian[2], Derek J. Sebastian[1]; [1]Colorado State University, Fort Collins, CO, [2]CSU, Loveland, CO (130)

Herbicides are commonly used to decrease the abundance of invasive weeds in natural areas as a first essential management step. Understanding a herbicide's weed control spectrum is important and understanding that herbicide's potential to injure native plants is equally important to successfully reclaim an infested natural area. Experiments were established on grazed rangeland in northwest Colorado in 2009 to assess the effects of aminopyralid and clopyralid on the native plant community where no invasive weeds were present. Aminopyralid was applied at 0.75 and 1.75 oz ai/A plus a non-ionic surfactant (NIS) at 0.25% v/v and at 1.75 oz ai/A without the

surfactant; and clopyralid was applied at 6 oz ai/A plus a NIS at 0.25% v/v. Herbicides were applied in early summer (Jul 10), late summer (Sep 4) and early fall (Oct 16). The design was a five (herbicide treatments) by three (application timings) factorial arranged as a randomized complete block with six replications. Density data (individual plants for forbs and shrubs; shoot density for grasses) were collected in late summer 2010, 2011, 2012, and 2013. All herbicide treatments applied in fall decreased forb density by 40 to 58% compared to untreated plots in 2010 1 year after treatment (YAT) and by 47 to 74% in 2013 (4 YAT). The addition of a surfactant did not alter forb overall injury from aminopyralid. Clopyralid injury was less than injury from aminopyralid. Individual forb species response to herbicides varied from almost complete elimination to small variation from the untreated plots to increased density compared to untreated plots. All shrubs were marginally affected by fall-applied herbicides and their density decreased 9 to 35% 1 YAT and 1 to 9% 4 YAT but shrub density in treated plots did not differ from untreated plots at any data collection. All grasses density increased in herbicide treated plots 60 to 121% 1 YAT and increased 259 to 539% 4 YAT. Total species richness in fall-applied plots ranged from 64 to 76% of richness in untreated plots 1 YAT and improved to 78 to 85% of richness in untreated plots 4 YAT. Forbs showed the greatest injury to fall applied aminopyralid or clopyralid and one species, aspen pea (*Lathyrus leucanthus*), was eliminated by aminopyralid at 1.75 oz ai/A (without a NIS) 4 YAT.

Aminocyclopyrachlor Application Proximity Affects Common Cottonwood Injury. Rodney G. Lym*; North Dakota State University, Fargo, ND (131)

Aminocyclopyrachlor (AMCP) was the active ingredient in the DuPont commercial herbicide formulation AImprelis@ which was sold in the turfgrass market starting in the fall of 2010. The company voluntarily withdrew the label in August 2011 because of reported tree damage following AMCP application to turf for weed control. Many of the reports concerned sensitive tree species, such as Norway spruce [*Picea abies* (L.) Karstand] and white pine (*Pinus strobus* L.); however, damage to other species including broadleaf trees also was reported. The purpose of this research was to evaluate how the distance of AMCP application from a sensitive tree species affected injury. The experiment was established on May 2, 2012 in a preserve area within the boundaries of the Maple River Dam in southeast North Dakota. A row of volunteer common cottonwood (*Populus deltoides* W. Bartram ex Marshall) approximately 5 years old had established away from all other woody species and were to be removed. AMCP plus chlorsulfuron at 2.4 + 0.95 oz/A or picloram at 16 oz/A was applied at the base, the dripline or 2X the dripline away from a selected tree. Treatments were applied using a hand-held four nozzle boom sprayer delivering 17 gpa at 35 psi in 7.5 foot width. The treatments were applied by circling the tree twice (not overlapping) for a total coverage area 15 feet wide. Care was taken to avoid treating the bark of trees when herbicide was applied at the base. Plots (single tree) were at least 50 feet on center apart and there were two replications. AMCP plus chlorsulfuron injury (leaf curling) first appeared approximately 42 DAT when application was made at the base or dripline of a tree and averaged 95 and 67% injury by 113 DAT (end of season). Cottonwood injury was less than 10% by 113 DAT when AMCP plus chlorsulfuron was applied at 2X the dripline. Picloram injury appeared in less than 13 DAT when the herbicide was applied at the base and within 30 DAT when applied at the dripline and 2X the dripline. Cottonwood injury averaged 100% by 70 DAT when picloram was applied at the base and the trees did not recover. Picloram applied at 2X the dripline averaged 70% injury 476 DAT (end of second season). In contrast, AMCP injury to common cottonwood 476 DAT averaged 70, 64, and 18% when applied at the base, dripline, and 2X the dripline, respectively. In summary, AMCP injury was generally less than picloram when applied near common cottonwood trees and decreased as application distance from the tree increased. However, AMCP injury was observed even when applied at 2X the dripline.

Penoxsulam + Oxyfluorfen (Pindar GT) Control of Shortpod Mustard (*Hirschfeldia incana*).
Vanelle F. Peterson*[1], Rick K. Mann[2]; [1]Dow AgroSciences, Mulino, OR, [2]Dow AgroSciences, Indianapolis, IN (132)

Pindar GT herbicide (penoxsulam plus oxyfluorfen, 0.083 lb + 3.93 lb a.i./gallon) combines two herbicide modes of action into one product. Oxyfluorfen is a PPO (protoporphyrinogen oxidase) inhibitor in HRAC mode of action group E. For many years, it has been the standard for residual weed control in many crops and is used for weed control in some non-crop areas. Penoxsulam is an ALS (acetolactate synthase) inhibitor in HRAC group B. It provides extended residual weed control at 0.016 to 0.032 lb a.i./acre. Penoxsulam alone is registered as Grasp® SC and Granite®SC herbicides in rice, as Galleon® herbicide for aquatic weed control and as Sapphire® and LockUp® herbicides for control of weeds in turf. The combination of penoxsulam with oxyfluorfen provides broad spectrum and long lasting pre-emergence and post-emergence control of difficult to control broadleaf weeds and some major grass species including horseweed (*Conyza canadensis*), hairy fleabane (*Conyza bonariensis*), cheeseweed (*Malva* spp), redstem filaree (*Erodium cicutarium*), shepherd's purse (*Capsella bursa-pastoris*), coast fiddleneck (*Amsinckia intermedia*), common chickweed (*Stellaria media*), London rocket (*Sisymbrium irio*), sowthistle (*Sonchus* spp), white clover (*Trifolium repens*), barnyardgrass (*Echinochloa crus-galli*), annual bluegrass (*Poa annua*), and others. Pindar GT controls weeds that are resistant to other herbicide classes. When applied during the winter dormant season in California, Pindar GT can provide up to six months control of weeds. It is currently registered for use in tree nut orchards and non-crop areas.

Many mustards are commonly found on roadsides in California, where vegetation mangers use bareground weed control, but recently herbicides used on roadsides have not been controlling shortpod mustard (*Hirschfeldia incana*). It is a tall, winter annual to short lived perennial. Once the plant is mature and dries out it can be a fire hazard along roadsides while its height at maturity can be a safety hazard by blocking visibility of guardrails and signs as well as being aesthetically undesirable. A need to control this particular mustard has increased over recent years because it is not adequately controlled by current herbicides registered for use on roadsides.

Two trials were established in Fresno and Woodland, CA to determine the efficacy of penoxsulam and oxyfluorfen alone, in the formulated product (Pindar GT) and in tank mixtures with other herbicides as an autumn pre-emergence application on shortpod mustard. Applications were made December 20, 2011 (Fresno) and December 8, 2011 (Woodland) with CO_2 backback sprayers at 30 GPA with 4 replications per treatment. Shortpod mustard was naturally occurring in Woodland and seeded into the trial site in Fresno.

The addition of penoxsulam to oxyfluorfen significantly increased control of shortpod mustard by about 40%. Penoxsulam + oxyfluorfen at 0.03 lb + 1.5 lb provided excellent (98%) control of shortpod mustard.at 6 months after application. Tank mixes of penoxsulam + oxyfluorfen at 0.03 + 1.5 lb with aminopyralid and/or dithiopyr improved overall bareground weed control. The addition of dithiopyr at 0.5 lb to oxyfluorfen at 1.5 lb also increased control of shortpod mustard (91% vs 68%, respectively) at 6 months after application. The best bareground tank mixtures with penoxsulam + oxyfluorfen (Pindar® GT herbicide) were with dithiopyr (Dimension® EC herbicide) or dithiopyr (Dimension® EC herbicide) + aminopyralid (Milestone® herbicide).

Table 1. Percent visual control and bareground cover of treatments for control of shortpod mustard 6 months after December 2011 application.

Active Ingredients	**Product Name**	**Rate (lb ae/A)**	**% visual control shortpod**	**% visual bareground cover**
dithiopyr + aminopyralid	Dimension EC + Milestone	0.5 + 0.11	68 bcd	61 b
dithiopyr + oxyfluorfen	Dimension EC + GoalTender®	0.5 + 1.5	91 ab	69 b
dithiopyr + penoxsulam + oxyfluorfen	Dimension EC + Pindar GT	0.5 + 0.03 + 1.47	98 a	83 a
aminopyralid + oxyfluorfen	Milestone + GoalTender	0.11 + 1.5	75 bcd	76 ab
Aminopyralid + penoxsulam + oxyfluorfen	Milestone + Pindar GT	0.11 + 0.03 + 1.47	97 a	75 ab
dithiopyr + aminopyralid + oxyfluorfen	Dimension EC + Milestone + GoalTender	0.5 + 0.11 + 1.5	86 abc	74ab
dithiopyr + aminopyralid + penoxsulam + oxyfluorfen	Dimension EC + Milestone + Pindar GT	0.5 + 0.11 + 0.03 + 1.47	98 a	88 a
dithiopyr	Dimension EC	0.5	68 bcd	41 cd
aminopyralid	Milestone	0.11	16 de	34 de
penoxsulam + oxyfluorfen	Pindar GT	0.03	98 a	76 ab
oxyfluorfen	GoalTender	1.5	59 bcde	55 bc
glyphosate	Accord® XRT II	2	0 e	28 e

	NOTE: All treatments (except trt 12) had glyphosate (Accord XRT II) added at 2 lb ae/A	

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PROJECT 2: WEEDS OF HORTICULTURAL CROPS

Does Glyphosate Negatively Affect High Density Apple Production Systems? Alan J. Raeder*, Ian C. Burke; Washington State University, Pullman, WA (069)

Recent popular press articles and observations of glyphosate injury in high density orchards have caused growers to become increasingly concerned about possible negative effects of glyphosate use in apple production systems. A study was established in 2013 in an orchard without significant recent glyphosate use history to determine if the use of glyphosate has any effect on tree growth, yield and fruit quality. The study was a RCB split-plot design. The main and split-plot factors were glyphosate use (840 g ae ha^{-1}, 1920 g ae ha^{-1}, or a nontreated check) and the presence of vegetation (no vegetation or a uniform stand of weeds), respectively. Glyphosate applications were applied on May 16th and July 11th. No injury attributed to glyphosate was observed. Plots with no vegetation yielded lower (77 apples $tree^{-1}$) than plots with vegetation (102 apples $tree^{-1}$). Fruit color in plots with vegetation (L value: 56.30; hue: 39.54) was different than in plots with no vegetation (L value: 53.14; hue: 35.30). Fruit color in the low rate treatment (L value: 56.34; hue: 40.08) was different than in the nontreated and high rate treatment (L value: 53.94 and 53.87, respectively; hue: 35.54 and 36.65, respectively). Negative effects of glyphosate in high density apple production systems were not evident. Continued efforts to understand if glyphosate affects high density apple orchards includes the monitoring of the trees as they break dormancy, assessment of production orchards with glyphosate injury symptoms, and a greenhouse experiment to study the absorption and translocation of C^{14}-labeled glyphosate.

Weeds on Organic Farms: A Comparison of Seedbank Data and Farmer Perceptions from New England, the Midwestern United States, California, and the Netherlands. Randa Jabbour*[1], Eric Gallandt[2], Kevin Gibson[3], Marleen Riemens[4], Richard Smith[5]; [1]University of Wyoming, Laramie, WY, [2]University of Maine, Orono, ME, [3]Purdue University, West Lafayette, IN, [4]Plant Research International, Wageningen, Netherlands, [5]University of California, Salinas, CA (070)

Weed communities on organic farms vary widely in density and diversity from their conventionally managed counterparts. We will present a detailed characterization of weed seedbanks on 91 organic farms from four distinct regions: northern New England, the Midwestern United States, the Central Valley in California, and the Netherlands. Soil samples were collected to a depth of 10 cm from 5 fields at each farm in 2010 or 2011, and then germinated in the greenhouse. Germinable weed seedbank density, diversity measures including richness and evenness, and community composition were measured. Seedbank density varied widely between farms and regions. California organic farms had significantly lower seedbank densities than New England organic farms. Weed species community composition revealed shared and unique weeds of concern in each region. There were also associations between community composition and farmer perceptions of their most problematic weeds. For example, on New England farms, hairy galinsoga *Galinsoga ciliata* and crabgrass *Digitaria spp.* were most often reported as the most problematic weeds. Notably, the most unevenly distributed seedbank communities in New England were consistently dominated by *Digitaria* species. We will highlight distinctive management strategies and philosophies in each region, as well as implications for outreach.

Evaluation of Integrated Strategies to Reduce Weed Interference in Table Beets and Related Crops. Ed Peachey*; Oregon State University, 97331, OR (071)

Deregulation of glyphosate tolerant sugarbeets may cause the loss of several important herbicides on the market, unless glyphosate resistant species threaten sugarbeet production to the point where glyphosate is ineffective and traditionalherbicides such as pyrazon return to the market. To address current and anticipated weed control challenges by table beet growers in western Oregon, three trials were established over two years to evaluate alternative herbicides and cultivation strategies for weed control in table beets and other related crops. In 2012, several herbicides were screened for efficacy and crop safety on table beets, chard, and spinach. S-metolachlor caused the least injury to the beets with reasonable weed control early but insufficient weed control by seasons end, even though the plots were cultivated. Pyroxasulfone improved weed control compared to s-metolachlor but caused more injury to beets than s-metolachlor. The combination of s-metolachlor (0.48 lb ai/A) plus ethofumesate (0.5 lb ai/A) gave the best yield, even though weed control was relatively poor. Increasing the rate of s-metolachlor to 0.63 lb ai/A and applying it as a tankmix with ethofumesate PRE improved weed control but not improve beet yield. S-metolachlor PRE fb triflusulfuron at 2-leaf had the largest beet root yield, and weed control averaged 90% at harvest. Swiss chard also was tolerant to triflusulfuron. In a second trial in 2012, a two factor RCBD was used to evaluate cultivation efficacy with and without and preemergence herbicides. Bezzerides spyders and torsion bars were used in concert with between-row sweeps for cultivation at cotyledon, 2-leaf and 4-leaf beet growth stages. The PRE tankmix completely controlled pigweed and common purslane and also was effective at controlling hairy nightshade and lambsquarters. Cultivation increased control of hairy nightshade relative to the uncultivated treatment. Cultivation timing with the spyders did not have a significant influence on weed control except when applied to cotyledon and 4-leaf beets. The third experiment in 2013 tested the weed control efficacy of four factors in table beets including PRE herbicide (s-metolachlor, 0.31 lb ai/A), cultivation timing (using the Bezzerides spyders and between row sweeps), and efficacy of triflusulfuron (0.023 to 0.046 lb ai/A) with and without phenmedipham (0.24 to 0.48 lb ai/). Important factors regulating weed control were analyzed with contrast analysis and indicated that weed control at harvest was influenced primarily by whether s-metolachlor and ethofumesate were applied after planting. Regression analysis indicated that weed control was the primary determinant of yield. The second factor influencing weed control at harvest was cultivation, which on average improved weed control from 70 to 88% when used with PRE herbicide. Averaged over all treatments, triflusulfuron applied at the 4-leaf beet stage controlled weeds better than when applied at the 2-leaf stage (88 vs. 70 % control), but did not significantly improve beet root yield. When phenmedipham was tankmixed with triflusulfuron, it also controlled weeds better at the 4-leaf stage than the 2-leaf stage (86 vs. 75% control). Cultivation at 2-leaf provided better weed control than at 4-leaf when PRE herbicides were applied. Late cultivation (4-leaf) may have reduced weed control provided by the PRE herbicide. The best weed control was with PRE herbicide fb triflusulfuron at 2-leaf followed one day later by a 2-leaf cultivation, and this treatment also yielded the most beets.

Mesotrione: A Novel Mode of Action Herbicide for use in Tree Nut, Pome Fruit, Stone Fruit, and Citrus Crops. Eric K. Rawls[1], Les Glasgow[2], Thomas H. Beckett[3], Ryan S. Bounds[4], Keith D. Burnell[5], Joshua I. Adkins*[6], Derrick L. Hammons[7]; [1]Syngenta, Vero Beach, FL, [2]Syngenta, Greensboro, NC, [3]Syngenta Crop Protection, Greensboro, NC, [4]Syngenta, Visalia, CA, [5]Syngenta, North Rose, NY,[6]Syngenta, Richland, WA, [7]Syngenta, Esparto, CA (072)

Mesotrione is a novel herbicide for the tree nut and fruit market that provides systemic preemergence and postemergence weed control. Mesotrione is readily taken up by leaves, shoots or roots, and is translocated in both the xylem and phloem. The mode of action is through competitive inhibition of the HPPD (4-hydroxyphenyl-pyruvate dioxygenase) enzyme which ultimately causes the destruction of chlorophyll, accounting for the typical white “bleaching” symptoms of herbicidal activity. Benefits of the herbicide include: flexibility of pre and post-emergence application timing; low use rates; tank mix flexibility; excellent crop tolerance; excellent efficacy on weed biotypes resistant to other herbicide classes. The use rates range from 105 - 210 g ai/ha applied post-emergence with glyphosate or paraquat, or alone as a pre-emergence application. A maximum of three applications and 420 g ai/ha can be applied per year. Mesotrione is primarily a broadleaf herbicide with significant activity on some grass and sedge species. Key weed species controlled or partially controlled by mesotrione include: pigweeds (*Amaranthus* spp), common lambsquarters (*Chenopodium album*), nightshades (*Solanum* spp), ragweed (*Ambrosia* sp.), morningglory (*Ipomoea* sp.), spanish needles (*Bidens bipinnata*), Asiatic dayflower (*Commelina communis*), hairy fleabane (*Conyza bonariensis*), horseweed (*Conyza canadensis*), large crabgrass (*Digitaria sanguinalis*), broadleaf signalgrass (*Brachiaria platyphylla*), fall panicum (*Panicum dichotomiflorum*), and yellow nutsedge (*Cyperus esculentus*). Field trials have been conducted since 2009 in all major tree crop growing regions. Results indicate that mesotrione alone can provide effective control of many broadleaf weed species, however, overall weed spectrum and control can be improved by the addition of tank mix partners. Mesotrione gives growers another management tool for weed control and when used in combination with glyphosate or paraquat can improve burndown and provide residual control of problematic weeds.

Weed Control with Pyroxasulfone, Fomesafen, and Linuron in Pacific Northwest Potato Production. Joel Felix*[1], Rick A. Boydston[2], Pamela Hutchinson[3]; [1]Oregon State University, Malheaur Experiment Station, Ontario, OR, [2]USDA-ARS, Prosser, WA, [3]University of Idaho, Aberdeen, ID (073)

Weeds present a major production concern for potato growers because they often reduce yield, impede harvest, and could possibly serve as alternative hosts for other crop pests. Two- or three-way herbicide tank mixtures are often needed in order to expand the weed control spectrum and provide season-long weed control. Studies were conducted in 2013 in Oregon, Washington, and Idaho to evaluate weed control with pyroxasulfone, fomesafen, and linuron when tank-mixed with *s*-metolachlor, dimethenamid-p, or pendimethalin at 149, 280, 840, 1,490, 940, or 1,120 g ai ha^{-1}, respectively. Herbicide treatments were applied after hilling, prior to potato and weed emergence, and sprinkler incorporated within 6 hours of application. Regardless of treatment, <5% injury consisting mainly of chlorosis was observed at each site. Late season evaluations at 101 to 125 DAT representing season-long weed control indicated common lambsquarters was controlled from 88 to 99% across herbicide treatments. Season-long control for*Amaranthus* species ranged from 83 to 100% at OR and 95 to 100% at ID. Season-long hairy nightshade control at OR, WA, and ID was 64 to 98%, 83 to 100%, and >96%, respectively, across herbicide treatments. Russian thistle was only present at the WA site and was controlled 77 to 91% with treatments including fomesafen compared to 90 to 96% for treatments that included metribuzin. Linuron tank-mixed with *S*-metolachlor did not control Russian thistle, while mixing linuron with pendimethalin provided only 35% control. Kochia was only present at the OR site, and season-long control ranged from 84 to 100% for treatments that included fomesafen, pyroxasulfone, and/or metribuzin. Tank mixtures of linuron plus *S*-metolachlor or pendimethalin provided 41 to 69% kochia control, respectively. The U.S. No. 1 potato yield (tubers weighing at least 113 g and with no defects) reflected the level of weed control at each site. Fomesafen plus *S*-metolachlor resulted in the highest U.S. No. 1 yield (56.5 MT/ha) at OR, while the linuron plus pendimethalin treatment yielded the lowest at 20.7 MT/ha largely due to competition with kochia. The U.S. No.1 potato yield at WA was lowest with the linuron plus pendimethalin combination largely due to competition from uncontrolled Russian thistle at that location. The mixtures that included fomesafen, pyraxasulfone and/or metribuzin provided U.S. No.1 yield ranging from 59.0 to 65.0 MT/ha at WA; while the U.S. No.1 potato yield at ID ranged from 13.8 to 20 MT/ha across herbicide treatments. The lower yields at Aberdeen, ID also reflect the relatively shorter growing season there than at the other sites. The results suggested that herbicide combinations that included pyroxasulfone and fomesafen could provide broad spectrum, season long weed control in the Pacific Northwest region.

Three Herbicides and Thirteen Potato Varieties. Pamela Hutchinson*, Brent Beutler, Celestine Miera, Brenda Kendall; University of Idaho, Aberdeen, ID (074)

Recently-released potato varieties- Alpine, Classic, Highland, Premier, and Western Russet, and Yukon Gem; and standard varieties- Russet Burbank, Ranger Russet, Shepody, Yukon Gold, and Dark Red Norland were planted into 3-row plots and hilled 2 wks later spring 2009 and 2010. In 2010, new releases Clearwater Russet and Huckleberry Gold were added to the trial. In 2011, both these varieties and only R. Norkotah, R. Burbank, Ranger Russet and Yukon Gem were tested. Each year, flumioxazin, dimethenamid-p, or fomesafen at 1X and 2X rates was applied preemergence just after hilling and sprinkler-incorporated with 0.5 inch irrigation water within 24 hrs. Nontreated variety-controls were included. Injury ratings and plant ht measurements were recorded periodically. The trial areas were kept weed-free. Potatoes were harvested from the center-rows and graded. In 2009 and 2010, late spring/early summer weather conditions were unusually cold and wet and injury such as stunting was visible early-season, especially in plots treated with 2X rates. Less vigorous emerging and slower early-season growing varieties, such as Russet Burbank or Premier Russet, were more affected than faster emerging, early-season growing varieties, such as Shepody. In 2009, flumioxazin caused stem and lower-leaf necrosis as a result of intense rainfall events splashing treated soil. In spite of injury any year, 1X rates did not usually cause yield reductions, regardless of herbicide, while 2X rates resulted in some losses. Overall, Russet Burbank and Western Russet were the varieties most often affected by the 2X rates. Within varieties, flumioxazin or dimethenamid-p usually affected yield more than fomesafen. Trial information was useful during 2009-2011 because growers were also experiencing injury on newly-released varieties which had never been tested for tolerance to these herbicides.

Melon and Weed Response to Herbicides. Lynn M. Sosnoskie*[1], Bradley D. Hanson[2], W. Thomas Lanini[1]; [1]University of California - Davis, Davis, CA, [2]University of California, Davis, CA (075)

According to the most recent statistics, the United States is the world's sixth largest producer of melons, with the majority of the country's production occurring in California, who leads the nation in both volume and value; the 2011 crop of cantaloupes and melons in California was worth an estimated $227 million. Weed control in melons is necessary to maximize yields, but can be difficult because of the limited availability of registered herbicides. The objective of this current study was to evaluate the effects of pre-emergence (PRE) herbicides, along with a layby herbicide, on melon safety and season-long weed control.

The 2013 research trial was seeded on 6 June at a research farm on the University of California–Davis campus. Soil at the site is a fine, silty loam (Yolo series). Both cantaloupe ('Oro Rico' and 'Yosemite') and honeydew ('Saturno') melons were evaluated in the study. Each main plot consisted of three sets of two-row sub-plots (one set for each type of melon) that were 30 feet in length and were on a 60 inch spacing. Every other bed was planted, allowing for 120 inches between seed lines. Herbicides in the trial included: ethalfluralin (Curbit at 4 pt/A), clomazone (Command at 0.55 pt/A), ethalfluralin plus clomazone (Strategy at 4 pt/A), halosulfuron (Sandea at 0.75 oz/A), metolachlor (Dual Magnum at 1.33 pt/A), sulfentrazone (Zeus at 3.2 oz/A) and trifluralin (Treflan at 1.5 pt/A). Except for the Treflan, which was applied at layby, herbicide applications were made after planting (using a backpack sprayer calibrated to 20 GPA), but prior to crop emergence, and incorporated with sprinkler irrigation. Crop size and weed cover and density were evaluated weekly to bi-weekly for the first 6-8 weeks of the experiment. Fruit were harvested from each plot at maturity

The lowest levels of weed control occurred in the Command plots and the untreated check (8-87% cover 3-6 weeks after crop emergence). All other herbicide programs provided good to excellent control of weeds (0-11% cover) for up to 6 weeks after crop emergence. The greatest amount of crop injury (plant sizes were sometimes reduced by >50%) was observed in the Zeus plots, which also provided the best weed control. Herbicide injury was still evident in the Zeus plots at 5 weeks after crop emergence. Control plots, at 5 weeks after emergence, showed reduced plant growth as the result of significant weed competition. Crop yields (total fruit numbers and weights per plot) were the lowest in the check and Command plots (86 fruit/plot, 312 lbs/plot), where weed cover was the greatest. Despite significant early season injury, Zeus-treated plots (109 fruit/plot, 380 lbs/plot) yielded better than the control treatment and as well as the Curbit (101 fruit/plot, 370 lbs/plot) standard. Strategy, Sandea and Dual Magnum performed as well as the Curbit standard.

Conclusions and Future Research:

- The lowest levels of weed control, across all melons, occurred in the Command plots and the untreated check. All other herbicide programs provided good to excellent early-season weed control

- The greatest amount of crop injury was observed in the Zeus plots, which also provided the best weed control. Herbicide injury was still evident in the Zeus plots at 5 weeks after crop emergence. Control plots, at 5 weeks after emergence, showed reduced plant growth as the result of significant weed competition.
- Crop yields (total fruit numbers and weights per plot) were lowest in the check and Command plots, where weed cover was the greatest.
- Despite significant early season injury, Zeus-treated plots yielded better than the control and as well as the Curbit standard.
- With respect to the combined effects of weed control, visible crop injury and yield, Strategy, Sandea and Dual Magnum performed as well as the Curbit standard.
- Future research will focus on: 1) the use of soil amendments in an attempt to prevent herbicide leaching into the seed zone (thereby reducing subsequent crop injury), 2) the use of Zeus at lower rates and in combination with other herbicides for weed control in melons, 3) evaluating the effects of soil type (sandy vs. loamy) and irrigation strategy (furrow vs. drip) on herbicide (particularly Dual Magnum) safety and performance, 4) comparing herbicide performance and safety in seeded and transplanted melons, 5) characterizing the effects of herbicide carryover and drift on melon injury and yield and 6) evaluating 'non-melon' herbicides for crop safety.

Selective Weed Control with Pyroxasulfone in Peppermint and Spearmint. Rick A. Boydston*; USDA-ARS, Prosser, WA (076)

The majority of the U.S. peppermint and spearmint is produced in the Pacific Northwest and Washington leads the nation in the production of mint oil valued at $76 million. Weed management in mint relies primarily on herbicides, with terbacil being the most used herbicide in mint. After nearly four decades of terbacil use in mint, both terbacil tolerant weed species and terbacil resistant weed species are common in mint production areas. Pyroxasulfone was tested in mint from 2009 to 2013 in Washington and controls terbacil resistant redroot pigweed and rattail fescue, two weeds that are increasing in Washington mint production. Peppermint and native spearmint were not significantly injured by pyroxasulfone applied at 0.19 lb ai/A to dormant peppermint and spearmint in late fall or late winter. Oil and hay yields of weed-free peppermint treated with 0.19 lb ai/A to 0.38 lb ai/A pyroxasulfone when mint was dormant were similar to that treated with a standard treatment of terbacil at 0.5 lb ai/A. Pyroxasulfone applied at 0.19 lb ai/A with 0.5 lb ai/A terbacil and 0.5 lb ai/A paraquat controlled rattail fescue 97% and redroot pigweed 100% in peppermint through mid-June. Pyroxasulfone applied at 0.13 or 0.19 lb ai/A to double cut peppermint on a sandy soil just after the first mint harvest injured peppermint and reduced hay and oil yields in the second harvest. To minimize potential injury to peppermint, pyroxasulfone should be applied to dormant mint during late fall or winter.

Irrigation and Nitrogen Fertilization Effects on White Clover Invasion in Turf. Kyle G. Frandsen*[1], Don W. Morishita[2], Tom Saliaz[3]; [1]University of Idaho, Kimberly, ID, [2]University of Idaho, Twin Falls, ID,[3]Mccain Foods, Burley, ID (077)

White clover is one of the most commonly found weeds in turf and persists well under mowed conditions. Common herbicides, such as dicamba or triclopyr, can be successful in controlling white clover if applied at correct timings and rates. However, little scientific research exists which specifically evaluates nitrogen fertility and irrigation management practices as a control method to reduce white clover in a turfgrass stand. Most turfgrass weed research evaluates weed control on weed species in the soil seed bank at the location where the research is conducted. Research was conducted in 2012 and 2013 to specifically evaluate white clover invasion and management under varying irrigation and nitrogen fertility regimes. Irrigation treatments were established by watering to meet 70, 90 and 110% of evapotranspiration for turf. The nitrogen rates were 0, 2.4, 4.9 and 7.3 g of nitrogen per m^2. The experimental design was a split block randomized complete block with three replications. Irrigation treatment was the main plot and nitrogen rate was the sub-plot. Nitrogen fertility treatment influenced clover counts throughout each month of the growing season, with a fertilizer by year interaction 5 out of the 7 months that were evaluated each year. Clover counts were the highest for the 0 and 2.4 g nitrogen treatments while clover counts were lowest for the 4.9 and 7.3 g nitrogen treatments. Differences in turfgrass color relative to fertilizer treatment were observed in all months except August and September. Color and quality ratings were similar in that generally the 0 g nitrogen treatment had the lowest color and quality ratings and the 7.3 g nitrogen treatment had the highest ratings. Generally, irrigation treatment was not shown to have a significant effect on clover encroachment or persistence.

Performance Highlights of New Herbicides for Use on Turfgrass Weeds in Arizona. Kai Umeda*; University of Arizona, Phoenix, AZ (078)

Amicarbazone and methiozolin have been investigated for selective postemergence *Poa annua* control in cool-season turfgrasses in Arizona with fall and spring application timings. Spring application results of sequential applications of amicarbazone at rates ranging from 0.088 to 0.175 lb a.i./A caused injury to creeping bentgrass on golf course putting greens. *P. annua* control was initially acceptable and then declined to less than acceptable levels. Methiozolin at 0.5 lb a.i./A applied four times at 10-day intervals during late April through May 2013 did not exhibit acceptable efficacy against *P. annua* while being completely safe on the bentgrass. Previous experiments showed fall applications to be efficacious.

Penoxsulam is being introduced commercially for use as a spring transition aid to remove perennial ryegrass from bermudagrass. Penoxsulam at 0.058 lb a.i./A was applied in early May 2013 and within a week caused minimal perennial ryegrass injury as growth reduction. At the end of May, penoxsulam removed only 30% of the ryegrass compared to herbicides that removed 100% of the ryegrass. A newly introduced combination product containing foramsulfuron plus halosulfuron plus thiencarbazone removed nearly all of the ryegrass in early June while showing 25% ryegrass injury within a week of a single application. During the summer the combination product demonstrated marginally acceptable purple nutsedge control at 82% with sequential applications. The combination product offered slightly better observable control of nutsedge compared to halosulfuron applied alone.

In a third small plot experiment, the combination product gave less than acceptable control of maturing goosegrass. Topramezone at 0.006 lb a.i./A gave acceptable control of goosegrass while causing undesirable bleaching of bermudagrass turf. Higher rates of topramezone at 0.011 to 0.022 lb a.i./A caused increasing phytotoxicity of the turf and goosegrass control was similar at 93 to 95%.

Sulfentrazone at 0.375 lb a.i./A applied sequentially before sulfonylurea herbicides for purple nutsedge control was better than being applied sequentially after sulfonylurea herbicides. At 4 weeks after the sequential applications, the sulfentrazone followed by sulfonylurea herbicides performed nearly similar as the sequential sulfonylurea herbicides.

PROJECT 3: WEEDS OF AGRONOMIC CROPS

Kochia Samples from North Dakota with Variable Response to Fluroxypyr. Kirk A. Howatt*, Mark Ciernia; NDSU, Fargo, ND (079)

Nearly 80 samples of kochia seed, mainly from the eastern third of North Dakota, were collected under suspicion of resistance to glyphosate. As many as 60% of these kochia samples demonstrated greater survival than expected when treated in the greenhouse with fluroxypyr as an alternative for controlling glyphosate-resistant kochia biotypes. Two seed samples expressing low to moderate survival and two samples demonstrating vigorous survival were selected for dose response experiment and compared with a highly susceptible seed collection from an area without control concerns. Plants were grown to 5 to 6 cm and treated with fluroxypyr at 10 rates from 0 to 1680 g/ha. Collections with low to moderate survival in screening responded similarly to the susceptible control. However, the samples previously producing more vigorous regrowth demonstrated about six-fold resistance to fluroxypyr, and 90% control was only achieved with fluroxypyr at 1120 g/ha or more. In a separate study, the same kochia collections were treated with 70 and 140 g/ha fluroxypyr at heights of 1, 3, 5, and 10 cm. Control of the resistant kochia collections tended to increase as size at application increased, but control 28 DAT did not reach 75%. Optimum size for susceptible kochia control typically was 3 to 5 cm and 90% control was achieved. While the majority of original samples fell in the low to moderate survival group, a total of five collections could possess resistance to fluroxypyr. These samples represent a broad geography of the original collection area and indicate reason for caution in development of weed control programs.

Ecological Fitness of Auxinic Herbicide-Resistant Kochia. Vipan Kumar*, Prashant Jha, Aruna Varanasi; Montana State University, Huntley, MT (080)

Kochia biotypes resistant (R) to auxinic herbicides (dicamba/fluroxypyr) were documented in MT (1995) and other NGP states. However, it is unknown whether auxinic resistance confers any ecological fitness cost to R kochia. The objective of this research was to determine the relative fitness and competitive ability of kochia biotype from MT resistant to dicamba (5-fold) and fluroxypyr (3.1-fold) compared with a known susceptible (S) biotype. Seed germination of R biotype (near-isogenic line) was compared with the S biotype at 5, 10, 15, 20, 25, 30 and 35 C.

The R biotype had lower cumulative germination compared with the S biotype at all temperatures tested. A non-competitive comparative growth study for R and S biotypes was conducted in the greenhouse. Also, replacement series experiments with five proportions of R and S biotypes (0:100, 25:75, 50:50, 75:25, and 100:0) were conducted to determine the relative competing ability of the R and S biotypes. R biotype exhibited lower growth characteristics than the S biotype on the basis of plant height, number of leaves and number of branches, shoot dry weight, and total leaf area. Furthermore, seed production of R biotype (16,341 seeds plant^{-1}) was less compared with the S biotype (22,214 seeds plant^{-1}). Seeds of the R biotype were smaller than those of the S biotype. These results indicate that auxinic-resistance trait confers fitness penalty in kochia. Therefore, dicamba- and/or fluroxypyr-resistant kochia is less likely to persist in field populations in the absence of selection pressure from these auxinic herbicides.

Common Lambsquarters Control: Chapter 3 - Adjuvants. Rich Zollinger*; North Dakota State University, Fargo, ND (081)

Herbicide labels are generally deficient in describing sufficient information to optimize herbicide activity through adjuvants. Glyphosate labels may restrict use of surfactants, state that no additional surfactant is needed, or allow use by voluntary action. Many weed species are >easy-to-wet= and have high retention of the spray droplets. These species may not show a significant increase in herbicide activity through adjuvant enhancement in moderate environmental conditions and on small weeds that are not stressed. Many weeds are >hard-to-wet= which decreases retention of spray droplet and reduces efficacy. Lambquarters and many grasses are >hard-to-wet=. Control of >hard-to-wet= species may increase if the most efficacious adjuvants were identified on herbicide labels and recommended at optimum rates. Several field and greenhouse studies were conducted over multiple years to observe adjuvant affect on Chenopodium species from herbicides. Increasing water volume had a slight affect in improving herbicide efficacy but addition of nonionic surfactants (NIS) that improved retention had a greater effect. Lambsquarters efficacy from a full-load glyphosate formulation varied widely with 13% (no NIS), to 78% (NIS at 1%). Several commercial NIS adjuvants were tested with glyphosate and control ranged from 10% to 78%. NIS adjuvants were applied with no-surfactant load, partial-load, and full-load glyphosate formulations and control ranged from 17% to 73%. Some NIS adjuvants that increased lambsquarters control in a no-load glyphosate showed reduced control when applied with partial- or full-load glyphosate formulations. NIS adjuvant enhancement was most pronounced when used with no- or partial-load glyphosate formulations but increased control was observed to a lesser extent when NIS was used with full-load formulations. The results show that control of lambsquarters may improve when effective NIS adjuvants are added at higher rates than commercially used with all formulations of glyphosate. NDSU Extension adjuvant use recommendations to growers have been changed to add NIS at 0.5% to 1% v/v for no-load, 0.25% to 0.5% v/v for partial-load, and 0.25% v/v for full-load glyphosate formulations.

Impact of Adjuvants on Herbicide Efficacy and Droplet Spectra. Cody F. Creech*[1], Ryan S. Henry[1], William Bagely[2], Lowell Sandell[3], Greg Kruger[4]; [1]University of Nebraska-Lincoln, North Platte, NE,[2]Wilbur-Ellis, San Antonio, TX, [3]University of Nebraska-Lincoln, Lincoln, NE, [4]University of Nebraska, Lincoln, NE (082)

Adjuvants can alter spray quality and in some cases can increase the efficacy of herbicide applications. The potential activity of post-emergence herbicides is often limited by the inability of the herbicide to adequately cover or penetrate the leaf surface. The objective of this study was to evaluate the impact of different types of adjuvants when added to four herbicides and applied through three commonly used nozzles. The treatments consisted of four herbicides applied at reduced rates, a non-surfactant loaded glyphosate (0.79 kg ae ha^{-1}), fluazifop-P (0.07 kg ai ha^{-1}), lactofen (0.11 kg ai ha^{-1}) and dicamba (0.14 kg ae ha^{-1}). Each herbicide was applied alone and in combination with a non-ionic surfactant (NIS 0.25% v/v), crop oil concentrate (COC 1% v/v), methylated seed oil (MSO 1% v/v), high surfactant oil concentrate (HSOC 1% v/v), ammonium sulfate (AMS 20.37 g L^{-1}), and a drift reduction adjuvant (DRT 0.292 L ha^{-1}). Treatments were applied in field studies and in a greenhouse experiment. In addition, the droplet size spectrum for each treatment was determined using a laser diffraction system at the Pesticide Application Technology Laboratory (PAT Lab) in North Platte, NE. Field plots were 3 meters wide and 8 meters long and had a naturally occurring weed population that had also been supplemented by broadcasting velvetleaf (*Abutilon theophrasti*), grain amaranth (*Amaranthus hypochondriacus*), Palmer amaranth (*Amaranthus palmeri*), flax (*Linum usitatissimum*), and barnyard grass (*Echinochloa crus-galli*). Greenhouse species were similar but did not include Palmer amaranth or barnyard grass and included corn (*Zea mays*) and shattercane (*Sorghum bicolor*). The glyphosate, fluazifop-P, and dicamba were applied at 38 L/ha using an AIXR110015 nozzle and the lactofen was applied at 76 L/ha using an AIXR11003 nozzle. Treatments were applied using a CO_2 pressurized backpack sprayer in the field and a single nozzle track sprayer located at the PAT Lab. Visual estimations of injury were collected at 7, 14, and 28 days after treatment (DAT) using a scale of 0 – 100 where 0 = no injury and 100 = plant death. In addition, plants treated at the PAT Lab were clipped at the soil surface and wet weights were recorded. These samples were then dried and dry weights were recorded. Generally, the addition of adjuvants increased the efficacy of the four herbicides tested. Glyphosate efficacy improved with the addition of NIS and AMS. Lactofen, dicamba, and fluazifop-P all had improved efficacy with COC. The adjuvants performed differently with each herbicide and were often species specific. For all herbicides, the addition of adjuvants usually increased the droplet size with the exception of NIS which decreased droplet size. Adjuvants should be used if they are recommended on the herbicide label. Further testing is needed to understand which adjuvants are best suited for different application conditions and will increase the herbicide efficacy on the intended targets.

Preventing, Minimizing, Dreaming of Reduced Selection Pressure for Wild Oat Resistance.
Robert E. Blackshaw*[1], Neil Harker[2], John O'Donovan[3], Vern Baron[3], Kelly Turkington[2], Linda Hall[4], Eric Johnson[5], Chris Willenborg[6], Steve Shirtliffe[6], Robert Gulden[7], John Kobler[8], Denis Pageau[9]; [1]Agriculture and Agri-Food Canada, Lethbridge, AB, [2]Agriculture and Agri-Food Canada, Lacombe, AB,[3]Agriculture and Agr-Food Canada, Lacombe, AB, [4]University of Alberta, Edmonton, AB, [5]Agriculture and Agri-Food Canada, Scott, SK, [6]University of Saskatchewan, Saskatoon, SK, [7]University of Manitoba, Winnipeg, MB, [8]University of Guelph, New Liskeard, ON, [9]Agriculture and Agri-Food Canada, Normandin, QC (083)

Wild oat (*Avena fatua*) ranks as the second most abundant weed on the Canadian prairies and is by far the most economically important with over $500 million in herbicide expenditures spent annually on its control. Not surprisingly, widespread distribution and high herbicide use has resulted in wild oat being the greatest weed resistance problem in this region (present on 40% of cropland). Farmers require information on how best to manage existing resistant populations as well as reducing selection pressure for further resistance development. A multi-year field experiment (2010-2013) was conducted at eight sites examining various combinations of crop management practices such as higher crop seeding rates, early-cut barley silage, and diversified crop rotations that included winter annual crops or perennial forage alfalfa in the predominantly summer annual crop production system in Canada. These treatments were compared with a common grower rotation of wheat-canola with recommended rates of wild oat herbicides. Higher crop seeding rates of summer crops (canola, barley, wheat) were reasonably effective with 50% herbicide rates but not in the absence of herbicides. In contrast, without any herbicide for three years, various sequences of barley silage alternating with winter cereals (2X seeding rate) had similar wild oat densities to the standard rotation with full herbicide rates. At several sites, the lowest wild oat densities were attained with three continuous years of forage alfalfa (cut 2-3 times per year). Results indicate that viable crop production practices exist to manage wild oat with little or no herbicide. These findings will be utilized to provide farmers with advice on a more multi-faceted approach to wild oat management.

Impact of Environmental and Biological Stressors on the Demography and Ecological Fitness of Multiple Herbicide Resistant Wild oat (*Avena fatua*). Erin Burns*, William E. Dyer, Fabian Menalled, Erik A. Lehnhoff, Barbara K. Keith; Montana State University, Bozeman, MT (084)

To address possible fitness costs of multiple herbicide resistance (MHR) in a field setting, the objective of these studies were to compare the impacts of stressors on the demography and fitness of wild oat (*Avena fatua*) MHR and herbicide sensitive (HS) biotypes. The first year of a two year study was conducted in Bozeman, MT in 2013 following a split-plot randomized block design with four replications. Whole plots were assigned spring wheat seeded at a density of 67.3 kg ha^{-1} (low) or 101 kg ha^{-1} (high) and sub-plots were combinations of one of four targeted N levels (56, 112, 168, or 224 kg N ha^{-1}) and one of three wild oat treatments (HS1, MHR3, or MHR4). In October 2012, wild oat seeds were sown in each sub-plot at a density of 1,000 seeds m^{-2}. Plots were sprayed with flucarbazone (30 g a.i. ha^{-1}) at the wild oat 3-leaf stage. In the Fall, wild oat seed production, evaluated prior to wheat harvest, differed among lines ($p < 0.0001$) and was negatively affected by N rate ($p < 0.02$) and seeding density ($p < 0.01$). HS plants had a high mortality rate due to herbicide application and produced few seeds, and MHR plants produced the lowest number of seeds as nitrogen rate and wheat density increased. Overall, knowledge of fitness costs of herbicide resistance can allow for the design of weed management programs that exploit and manipulate the traits in a weed biotype that caused reduced fitness.

Management Options for Control of Glyphosate Resistant Kochia in Fallow. Charles P. Hicks*[1], James R. Bloomberg[2], Greg Hudec[3], Kevin Watteyne[4]; [1]Bayer CropScience, Fort Collins, CO, [2]Bayer CropScience, Research Triangle Park, NC, [3]Bayer CropScience, Manhattan, KS, [4]Bayer CropScience, Lincoln, NE (085)

The evolution and spread of glyphosate-resistant populations of *Kochia scoparia* in the western United States and Canada is an increasing concern and threat for growers. Since its' initial detection in 2007, glyphosate-resistant kochia has now been confirmed in six states including

Colorado, Kansas, Montana, Nebraska, North Dakota and South Dakota and also in the Canadian province of Alberta. A recent survey of western Kansas indicates that nearly one-third of the cropland that area is infested with glyphosate-resistance kochia. There is a need to develop alternative weed control programs to control glyphosate-resistant kochia in the wheat-fallow systems located in the western United States.

Two years of field testing confirmed that Corvus Herbicide (isoxaflutole plus thiencarbazone-methyl) applied pre-emergence in combination with PSII inhibitor herbicides such as atrazine or metribuzin can provide excellent residual control of kochia (both susceptible and glyphosate-resistant) populations. These treatments also provided excellent control of Russian thistle and puncturevine. Postemergence applications of Laudis Herbicide (tembotrione) or Huskie Herbicide (pyrasulfatole) combined with PSII inhibitors also provided excellent control of Kochia, Russian thistle and puncturevine populations but were more erratic in performance than pre-emergence applications due to hot, dry weather conditions experienced at several trial sites. Addition of dicamba or fluroxypyr-based herbicides to the postemergence spray programs improved consistency of weed control. These field studies demonstrate the value of HPPD herbicides for control of glyphosate- resistant kochia and support the importance of utilizing multiple and effective site-of-action herbicides in weed control programs.

Effect of Sprinkler Incorporation Timing on the Activity of Soil-Active Herbicides Applied with Glyphosate. Don W. Morishita[1], Kelli M. Belmont*[2], Kyle G. Frandsen[2]; [1]University of Idaho, Twin Falls, ID,[2]University of Idaho, Kimberly, ID (086)

Soil-active herbicides applied in combination with glyphosate can effectively control a broad-spectrum of weeds, reducing the added selection pressure for glyphosate resistant weeds when using glyphosate alone. A field experiment was conducted at the UI Kimberly Research and Extension Center in 2012 and 2013 to determine how soon sprinkler incorporation is needed following glyphosate plus soil-active herbicide applications for weed control. Experimental design was a 4 by 5 factorial RCB with four replications. Incorporation timing treatments were established by waiting 0, 3, 6, or 9 days before incorporation (DBI). All treatments except the untreated control were sprayed with 0.86 kg ha^{-1} glyphosate at the 2-leaf sugar beet growth stage. At the 4- to 6-leaf stage, glyphosate at 0.86 kg ha^{-1} was applied in combination with five soil-active herbicides: *s*-metolachlor, EPTC, ethofumesate, dimethenamid-P, and acetochlor. To incorporate the herbicides, 1.25 cm of water was applied over the entire study site. Common lambsquarters and green foxtail density at 14 and 27 days after the last application (DALA), wild oat and other weeds (combination of other weeds species that were small in number) at 14 DALA were affected by incorporation timing. There were consistently fewer total weeds in the 0 and 3 DBI treatments than 6 and 9 DBI at 14 and 27 DALA. In response to herbicides, green foxtail density was lowest with dimethenamid-P. Wild oat density was lowest with *s*-metolachlor. There were no differences in beet yield or quality in response to incorporation timing or herbicide treatment.

Controlling Glyphosate-Resistant Kochia in Key Cropping Systems. Brad Lindenmayer*[1], Phil Westra[2], Phil Stahlman[3], Greg Kruger[4], Edward Davis[5], Kirk Howatt[6], Aaron Franssen[7], Gary Pastushok[8], Les Glasgow[9]; [1]Syngenta Crop Protection, Perkins, OK, [2]Colorado State University, Fort Collins, CO, [3]Kansas State University, Manhattan, KS, [4]University of Nebraska, Lincoln, NE,

[5]Montana State University, Bozeman, MT, [6]North Dakota State University, Fargo, ND, [7]Syngenta Crop Protection, Seward, NE, [8]Syngenta Crop Protection, Fargo, ND, [9]Syngenta, Greensboro, NC (087)

A collaborative study between Syngenta and several universities was conducted with the objective of identifying herbicide solutions to control glyphosate-resistant (GR) *Kochia scoparia* in three important cropping-systems: corn, soybeans, and wheat. Thirty-eight different treatments were evaluated in three studies conducted at 11 locations over two years looking at pre-plant and postemergence applications for season-long control in corn and soybeans as well as a rescue application made post-harvest in wheat. Treatments that combined PS-I and PS-II or HPPD inhibiting herbicides pre-plant in corn and soybeans were generally the most effective (i.e. combinations of paraquat, atrazine, metribuzin, mesotrione or isoxaflutole). Treatments relying heavily on glyphosate or auxinic herbicides pre-plant were typically less effective. Postemergence applications provided little additional control in corn and soybeans, indicating the importance of early-season control. While rescue applications made post-harvest in wheat were predictably less effective, the use of paraquat was key for kochia control with treatments of glyphosate or auxinic herbicides resulting in little control. Results from these studies suggest that there are several viable options available for GR kochia control. Early-season control is paramount and season-long GR kochia control in corn and soybeans can be achieved through a program combining a burndown plus residual pre-plant herbicide application followed by a postemergence application to control any subsequent weed flushes. Wheat fields with failed in-crop GR kochia control can be salvaged with post-harvest applications of paraquat. As a best practice, diverse mode-of-action combinations control GR kochia and prevent further selection pressure for resistance.

Tomato Injury and Downwind Deposition from Aerial Applications of Glyphosate. Ryan S. Henry*[1], Cody F. Creech[1], Brad Fritz[2], Clint Hoffmann[2], William Bagely[3], Andrew Hewitt[4], Greg Kruger[5];[1]University of Nebraska-Lincoln, North Platte, NE, [2]USDA-ARS, College Station, TX, [3]Wilbur-Ellis, San Antonio, TX, [4]UNL, North Platte, NE, [5]University of Nebraska, Lincoln, NE (088)

Aerial application of pesticides is a common and important tool in agriculture, pasture, and forestry systems in the US. This application technique can be sensitive to pesticide drift for a variety of reasons, including airspeed effects on droplet size, release height, and equipment setup. Studies examining the drift potential of a pesticide application have historically measured only pesticide deposition downwind of the application site. This is commonly done using a fluorescent dye as a proxy for the active ingredient and capturing the dye using sample media such as mylar plates, petri dishes, or strings. The present study combines this technique with a sensitive plant to serve as bio-indicators of pesticide drift. An Air Tractor 402B aircraft was used in this study to apply two separate tank mixtures, one being glyphosate alone and the other being glyphosate plus a drift reducing adjuvant. Downwind sampling of pesticide drift was made using mylar plates, tomato (*Solanum lycopersicum*), and monofilament strings up to 210 feet away from the application site. Visual damage was observed on the tomato plants at virtually all sampling locations, although deposition data from the mylar plates was less than one percent of the applied rate. This experiment highlights the importance of using bio-indicators in future drift studies and will aid in improving application technologies and regulations.

Current Status of Herbicide-Resistant Kochia in Montana. Prashant Jha*, Aruna Varanasi, Vipan Kumar, Shane Leland; Montana State University, Huntley, MT (089)

Herbicide-resistant kochia is an increasing concern for growers in the Northern Great Plains (NGP), including Montana. Based on our recent confirmation of glyphosate resistance in kochia accessions from Montana, a random field survey was conducted in fall of 2013 to determine the distribution and frequency of herbicide-resistant [glyphosate-, dicamba-, and ALS-inhibitor herbicide] kochia in northern Montana. Kochia populations (fully mature seeds) were sampled from chemical fallow-wheat fields, field edges/ fence lines, and roadsides. A total of 140 populations were included in the survey. Seeds from a survey sample were planted on the surface of commercial potting mix in flat trays in the greenhouse at the MSU Southern Agricultural Research Center, Huntley, MT. Each tray comprised of 40 kochia seedlings, with three replicated trays for each herbicide treatment and population combination. Kochia plants were treated with discriminating dose of the herbicide [glyphosate (0.870 kg ai ha^{-1}), dicamba (0.28 kg ai ha^{-1}), or thifensulfuron + tribenuron + metsulfuron (0.018 kg ai ha^{-1})] at the 8- to 10-cm-weed height. At 21 DAA, plant response to herbicide application was visually scored as susceptible: dead or nearly dead, or resistant: some injury but new growth, or no injury, in comparison to herbicide-treated and untreated susceptible and resistant control populations. Based on the screening of 80 populations so far, the frequency of glyphosate-resistant (GR) individuals varied from 18 to 96% in Hill County, 66 to 100% in Toole County, and 64 to 98% in Liberty County kochia populations. ALS-inhibitor-resistance (ALS-R) was found in >90% of the survey populations, with resistance frequency of 67 to 100% in a population. The frequency of dicamba-resistant (DR) individuals in confirmed populations varied from 2 to 51%, which was relatively less compared with the GR and ALS-R. Out of 80, 25 populations were resistant to all three herbicide modes of action (GR, ALS-R, and DR), whereas 35 populations showed two-way resistance (ALS-R and DR). Results from this research suggest that kochia populations with multiple resistance to glyphosate, ALS-inhibitors, and/or dicamba have evolved, and appear to be widespread in northern Montana farm fields. Occurrence of moderate to high frequencies of resistance warrants growers to adopt reactive herbicide resistance management strategies. Furthermore, resistance at low frequencies suggests the need for proactive resistance education to growers in MT and adjacent states in the NGP region.

Field Response of Suspected Fluroxypyr Resistant Kochia Populations. Patricia Prasifka*[1], Joe Yenish[2], Karli Clark[3], Roger Gast[4]; [1]Dow AgroSciences, West Fargo, ND, [2]Dow AgroSciences, Billings, MT,[3]Dow AgroSciences, Choteau, MT, [4]Dow AgroSciences, Indianapolis, IN (090)

During the 2012 season, growers in ND and northwestern MN sent in approximately 80 kochia seed samples to North Dakota State University (NDSU) to be evaluated for resistance to glyphosate and fluroxypyr. Only one sample was sent in due to suspected resistance to fluroxypyr, the rest were sent in due to suspected glyphosate resistance. Greenhouse trials at NDSU have shown varied levels of susceptibility to fluroxypyr in six samples. In order to confirm resistance, scientists are required to conduct greenhouse trials such as these to characterize resistance in the populations. However, an additional important criterion for confirmation of herbicide resistance is to demonstrate practical field impact. In 2013, to that end, Dow AgroSciences identified three field sites from which growers had submitted seed to NDSU for greenhouse testing and were shown to be difficult to control under greenhouse conditions. Field trials were placed at each of these sites; two locations were within a spring wheat crop (Rugby and Beach, ND) and a third within fallow (Dickinson, ND). The objective of the field trials was to test current commercial products at labeled rates to determine field efficacy against these kochia populations. At both the Rugby and Beach locations, all fluroxypyr-containing treatments showed high levels of control (>90% or >85% control, respectively). However, due to the lack of crop competition in the fallow at the Dickinson location and the fact that the kochia plants treated were larger than optimal for control (average height 6”), all treatments tended to have lower levels of control than at Rugby and Beach. Nevertheless, fluroxypyr-containing treatments provided control greater than or equal to treatments of bromoxynil, pyrasulfotole, or carfentrazone. Despite the fact that fluroxypyr resistance was suspected based on the earlier greenhouse trials, these trials showed that kochia control with fluroxypyr-containing treatments was greater than or equal to treatments that did not contain fluroxypyr under field conditions.

Updates on Molecular Response of Glyphosate Resistant Giant Ragweed (*Ambrosia trifida*). Christopher R. Van Horn, Phil Westra*; Colorado State University, Fort Collins, CO (099)

The introduction of glyphosate resistant crops along with widespread multiple in-season applications of glyphosate as part of weed management strategies that fail to address long-term weed control have provided the perfect scenario to foster the recent boom in glyphosate resistant weeds. In order to implement best strategies to manage glyphosate resistant weeds, it is important to understand the mechanism of resistance. Glyphosate targets and inhibits the enzyme 5-enolpyruvalshikimate-3-phosphate synthase (EPSPS), which prevents the synthesis of essential aromatic amino acids. We have investigated the mechanism of glyphosate resistance using twenty-two geographically diverse giant ragweed populations. From these populations we have characterized three phenotypic responses to glyphosate treatment: susceptible, resistant slow response, and resistant rapid necrosis. Observational data suggests that a carbon source is a necessary component to stimulate the rapid necrosis response. Sequence analysis showed no nucleotide mutation at the Proline-106 target site region across all populations sequenced. Analysis of EPSPS protein level using western blotting suggested no evidence of increased EPSPS in either glyphosate resistant or susceptible populations. Shikimate data suggests a translocation-based resistance mechanism may be involved. Observational data suggests that a very rapid transcriptional signal may be causing the initiation of the rapid necrosis response. Future research will require a transcriptomics approach to investigate gene expression patterns during this response. These initial results provide a much needed framework for future glyphosate resistance research in giant ragweed. With this research, we can continue to work toward sustainable forms of herbicide weed management.

Management of Herbicide Resistant Palmer Amaranth in Arizona. William B. McCloskey*; University of Arizona, Tucson, AZ (100)

Seed was collected in July and August of 2012 from a population of Palmer amaranth, *Amaranthus Palmerii*, in Buckeye, AZ in western Maricopa County suspected of being resistant to glyphosate due to control failures. For comparison, seed was also collected from two known glyphosate susceptible Palmer amaranth populations, one at the University Of Arizona Maricopa Agricultural Center (MAC) and the other in a riparian area near Sahuarita, AZ along the Santa Cruz River. These initial seed collections were screened for resistance to both glyphosate and pyrithiobac-Na. In collaboration with Pest Control Advisors, seed was collected in additional locations in Maricopa County in the summer of 2013 in response to glyphosate control failures. In all experiments, seeds of each biotype were planted in 4 inch pots, plants were grown in a greenhouse to the 4 to 6 true leaf growth stage and then sprayed with various rates of glyphosate and pyrithiobac-Na. The herbicide treatments were applied using a CO_2 pressurized sprayer and flat fan nozzles (XR8001) calibrated to deliver 10 GPA at 24 PSI. In the first experiment, the Buckeye biotype showed little response to slight stunting at glyphosate rates of 0.56, 0.75, 1.5 and 3.0 lb ae/A. In contrast, the Maricopa biotype was killed by rates of 0.36 and 0.75 kg ae glyphosate/ha. In the second experiment, the phytotoxic responses to increasing glyphosate rates from 0.01 to 0.36 lb ae/A 14 days after treatment (DAT) were 3.5 to 9.9 for the Maricopa biotype (0 to 10 scale with 10 representing death). In contrast, the phytotoxic responses to increasing glyphosate rates from 2.67 to 9 lb ae/A 14 DAT were 3.5 to 6.6 for the Buckeye biotype. The Buckeye plants were severely stunted and chlorotic for a period of two weeks after treatment but eventually recovered, resumed growth and began flowering in the greenhouse. Additional dose response experiments showed that the original putative glyphosate resistant Buckeye population was about 100 fold more tolerant of glyphosate than susceptible populations in Maricopa and Sahuarita, AZ. In addition, Palmer amaranth plants in other locations many kilometers from the field where resistant seeds were first collected are also highly resistant to glyphosate. To make matters worse for alfalfa and cotton producers, dose-response experiments showed that the Palmer amaranth populations that were highly resistant to glyphosate were also more tolerant of pyrithiobac-Na than susceptible populations in Maricopa and Sahuarita, AZ. Palmer amaranth is native to the desert southwest and is ubiquitous following summer monsoon rainfall with many plants growing along roadsides, in drainage ditches and other low lying areas not associated with agricultural fields. Plants growing in these areas could become reservoirs of the herbicide resistance traits; thus there is a significant risk that the herbicide resistance traits will spread to other agricultural areas in Arizona. In anticipation of the deregulation of dicamba resistant cotton, experiments were conducted to compare efficacy of dicamba, glufosinate and glyphosate for control of Palmer amaranth and ivyleaf morningglory.

Safety of Encapsulated Acetochlor to replanted Glyphosate-resistant Sugarbeet. David A. Claypool*, Andrew R. Kniss; University of Wyoming, Laramie, WY (101)

A field study was conducted at the Sustainable Agriculture Research and Extension Center near Lingle, Wyoming, in 2013 to evaluate safety of encapsulated acetochlor to replanted glyphosate-resistant sugarbeet. Acetochlor was applied preplant on May 2 at rates of 1.125, 2.25, and 3.375 lbs ai/A; an untreated check was included. Sugarbeet ('60RR27') was planted in 30-inch rows at a rate of 65,000 seeds per acre into treated soil in a sprinkler-irrigated field on May 6, 22, 30, June 5, 11, and 18. Soils at the site were Haverson and McCook loams (42% sand, 37% silt, 21% clay, 1.4% organic matter, pH 7.8, and CEC 19.6). Herbicide treatments were applied with a CO_2-pressurized knapsack sprayer delivering 16.8 gal/A at 30 psi with TeeJet 11002FFDG nozzles. Plots were 10 ft wide by 30 ft long and arranged in a strip block design with 4 replications. Sugarbeet populations were counted on June 3, 11, and 28, July 9 and 17, and August 18. Sugarbeet yield was collected from two rows per plot on October 1. Sugarbeet yield decreased as planting date was delayed. Sugarbeet stand was reduced by acetochlor PRE treatment. Due to variability in the data, an interaction between yield and stand was not observed, however, a combination of late planting and acetochlor preplant resulted in significant stand loss.

Establishing and Production of Roundup Ready Alfalfa and Cool Season Grass Forage Mixtures. Robert G. Wilson*; University of Nebraska-Lincoln, Scottsbluff, NE (102)

Experiments were conducted near Scottsbluff, Nebraska during 2012 and 2013 to examine weed control, stand longevity, production and relative feed value of alfalfa and cool season grass forage mixtures. Alfalfa 'DeKalb 41-18RR' was seeded alone or in combination with orchardgrass, tall fescue or meadow fescue in the spring of 2012. Weed control treatments consisted of bromoxynil applied at the two trifoliate leaf growth stage or glyphosate applied at the three trifoliate leaf growth stage only in the spring of 2012. Alfalfa density was greater at the time of the first cutting the first growing season in areas where weeds were controlled but by the spring of 2013 alfalfa density had declined to 5 plants per sq. ft. in all areas. Cool season perennial grass density followed a similar trend and declined from approximately 40 plants per sq. ft. to 4 plants per sq. ft. 13 months after seeding. Weed density averaged 36 plants per sq. ft. at the time of the first cutting in the nontreated and 2 plants per sq. ft. with the addition of a herbicide. The following growing season weed density averaged 26 plants per sq. ft. in the nontreated and 5 plants per sq. ft. where a herbicide had been utilized in 2012. The greatest reduction in weed density occurred where a mixture of alfalfa and orchardgrass was established and weeds in the first cutting were treated with bromoxynil. Over the two year period forage was harvested six times with total production at 12% moisture of 9.3, 13.0, 10.9 and 8.6 tons per acre for alfalfa, alfalfa plus orchardgrass, alfalfa plus tall fescue and alfalfa plus meadow fescue, respectively. Relative feed value of forage increased the first season first cutting when weeds were controlled with either bromoxynil or glyphosate. The combination of alfalfa with a cool season forage grass reduced forage relative feed value compared to alfalfa alone. Increases in relative feed value observed during the first season first cutting due to weed control did not carryover and influence relative feed value the second growing season.

Fertility and Chromosome Composition of Wheat x Jointed Goatgrass Backcross Progeny. Craig Beil*; Colorado State University, Fort Collins, CO (103)

Interest in the deregulation of transgenic wheat cultivars has led to increased concerns regarding the introgression of novel genes from wheat to jointed goatgrass. A greenhouse trial was conducted to determine the self-fertility rate of wheat x jointed goatgrass second generation backcross (BC_2) plants. Self-fertility rates were determined with germination studies of spikes collected from 37 BC_2 plants. Self-pollination of BC_2 plants led to the production of 1,148 BC_2S_1 (second generation backcrossed-first generation self-pollinated) plants. The mean germination rate of self-pollinated BC_2 plants was 7.01% with individual self-fertility rates ranging from 0.0% to 44.0%. This marks a significant increase in the germination percentage and the number of individuals produced from the BC_2 to the BC_2S_1 generation in the introgression process. A genomic *in situ* hybridization (GISH) procedure was developed to identifying whole chromosomes and translocation segments by genome in BC_2 progeny. A direct labeling procedure using the diploid species *Triticum urartu* and *Aegilops speltoides* as fluorescently labeled probes was used to identify the A- and B- genomes, respectively. Extensive cross-hybridization of labeled genomic probes made it unclear which chromosomes were the primary sites of targeted hybridization despite the use of varying concentrations and types of blocking DNA. Multi-color GISH proved to be an unreliable technique for differentiating multiple genomes simultaneously in wheat x jointed goatgrass backcross progeny. The development of a fluorescent labeling procedure that is genome or chromosome specific has the potential to identify genomes or chromosome regions that are more likely to introgress from wheat to jointed goatgrass.

Thiencarbazone-methyl -- A New Herbicide for Grass Control in Northern Plains Cereals.
Steven R. King*[1], Dean W. Maruska[2], Michael C. Smith[2], Kevin B. Thorsness[2], Charlie P. Hicks[2], George S. Simkins[2], Mark A. Wrucke[2]; [1]Bayer CropScience, Huntley, MT, [2]Bayer CropScience, RTP, NC (104)

Thiencarbazone-methyl, which will be marketed under the trade name of Varro® is a new postemergence grass herbicide that has been developed by Bayer CropScience for use in spring wheat, durum wheat, and winter wheat. Varro is a pre-formulated mixture containing thiencarbazone-methyl and the highly effective herbicide safener, mefenpyr-diethyl. Varro provides consistent control of the common annual grass species of the northern plains with excellent crop tolerance. Rapid microbial degradation is the primary degradation pathway for thiencarbazone-methyl and mefenpyr-diethyl has no soil activity. Therefore, Varro has an excellent crop rotation profile, allowing re-cropping to the major crops grown in the northern cereal production area including peas and lentils. Varro will be available for use in the northern plains cereal production area in 2014.

Varro is specially formulated as a liquid for easy handling and optimized for grass weed control. Varro at 6.85 fl oz/A can be applied to wheat from emergence up to 60 days prior to harvest. Grass weeds should be treated with Varro between the 1-leaf and 2-tiller stage of growth depending on the species. Varro also readily mixes with many broadleaf herbicides for cross-spectrum weed control.

Varro provides control of ACC-ase resistant and susceptible green and yellow foxtail, wild oat, and barnyardgrass and partial control of Persian darnell and Japanese brome. Varro also provides control or partial control of 12 broadleaf weed species that are common in the northern cereal production area of the United States. Varro in combination with broadleaf tankmix partners has been shown to increase the control of broadleaf weeds compared to the control provided by the broadleaf herbicides applied alone. Bromus species and foxtail barley were effectively controlled or managed with a tankmix of Olympus at 0.2 oz/A in field trials. Varro has been tested on spring wheat, durum wheat, and winter wheat varieties and crop tolerance was excellent. Broad spectrum grass control, excellent crop safety and recropping options, and the freedom to choose your broadleaf tankmix partner make Varro a valuable and easy to use tool for cereal grain producers.

Pyroxsulam in California and Arizona wheat. Jesse M. Richardson*[1], Byron B. Sleugh[2], Debbie G. Shatley[3], Roger Gast[4]; [1]Dow AgroSciences, Hesperia, CA, [2]Dow AgroSciences, Fresno, CA, [3]Dow AgroSciences, Lincoln, CA, [4]Dow AgroSciences, Indianapolis, IN (105)

Abstract not submitted.

Economics and Efficacy of Clopyralid, Florasulam, Fluroxypyr, MCPA, Thifensulfuron-Methyl, Tribenuron and Bromoxynil plus Pyrasulfotole Broadleaf Weed Control Systems. Alan J. Raeder*, Louise H. Lorent, Ian C. Burke; Washington State University, Pullman, WA (106)

Broadleaf herbicide options for weed control in wheat include multiple commercial pre-mixes and products containing individual active ingredients. The use of herbicides with overlapping efficacy to create a single mixture containing multiple modes of action (MOA) is one way to minimize development of herbicide resistance. The wide spectrum of available options can make it difficult to choose an optimum mixture of active ingredients and MOA for weed control in wheat and to plan a herbicide resistance management strategy. Four studies were conducted in 2012 and repeated in 2013 near Pullman, WA to evaluate the economics and efficacy of herbicide mixtures for control of broadleaf weeds in winter wheat, while also including multiple MOA for management of herbicide resistance development. Studies were arranged in a RCBD with four replications and included a nontreated check. Herbicides were applied within recommended label rates. Response factors were yield, wheat injury, and weed control. All treatments included pyrasulfotole plus bromoxynil (a group F plus C_3 herbicide) in mixture with a group B and/or O herbicide. Treatments in studies 1 and 2 included pyrasulfotole + bromoxynil in mixture with fluroxypyr + florasulam, fluroxypyr + clopyralid, fluroxypyr + thifensulfuron-methyl and tribenuron-methyl, MCPA + florasulam, MCPA + clopyralid, or MCPA and thifensulfuron-methyl + tribenuron-methyl. Studies 3 and 4 included pyrasulfotole + bromoxynil in mixture with florasulam + fluroxypyr, florasulam + pinoxaden, florasulam + MCPA, thifensulfuron-methyl and tribenuron-methyl + fluroxypyr, thifensulfuron-methyl + tribenuron-methyl, or thifensulfuron-methyl + tribenuron-methyl and MCPA. Grass herbicides were included in each trial, and were flucarbazone-sodium, mesosulfuron-methyl, pinoxaden, or pyroxsulam in studies 1, 2, 3, or 4, respectively. Yield was not different among treatments. Wheat injury was not different among treatments and did not exceed 5% injury, except in study 2 in 2012 and in the MCPA + florasulam mixture from study 1 in 2013 (5.5 ± 2.50 %). Control of annual broadleaf weeds was not different among treatments, except in study 1 in 2012 for control of mayweed chamomile when a mixture containing pyrasulfotole + bromoxynil and MCPA + clopyralid provided better control than pyrasulfotole + bromoxynil alone. The addition of fluroxypyr + florasulam (in studies 1, 2, and 4) and MCPA + clopyralid (in studies 1 and 2) added a MOA for broadleaf control for an increase in cost of \$15 ha^{-1}. The addition of florasulam plus fluroxypyr in study 3 added two MOA for an increase in cost of \$7.5 ha^{-1}per MOA. The cost of herbicide mixtures containing multiple MOA ranged from \$59 to \$77 ha^{-1} for three and \$74 to \$106 ha^{-1} for four MOA. In one case, it is feasible to include four MOA for \$3 less than three MOA for control of broadleaf weeds using premixed products.

Weed Management for Western Oregon Grass Seed Crops: Two Steps Forward, One Step Back. Daniel W. Curtis*, Kyle C. Roerig, Andrew G. Hulting, Carol Mallory-Smith; Oregon State University, Corvallis, OR (133)

An important aspect of grass seed management is the production of weed free seed. A study was initiated in 2012 in an established stand of ‘Silver Dollar’ perennial ryegrass to evaluate the effects of fall herbicide treatments for control of *Poa trivialis* and diuron resistant *Poa annua*, two of the worst contaminates in perennial ryegrass. The study was a complete block design with four replications. The perennial ryegrass was planted in 12 inch rows September 28, 2011. The crop was swathed, seed harvested, and straw chopped and removed in July of 2012. Plots consisted of perennial ryegrass with a fallow strip in the front of each plot. These strips were planted with three rows of *P. trivialis* and three rows of diuron resistant *P. annua* in the fall of 2012 immediately prior to herbicide applications. Twenty four herbicide treatments were evaluated in comparison to an untreated check. Herbicides were applied preemergence or as a combination of a preemergence application followed by a different herbicide applied 35 days later. Evaluations consisted of visual crop injury and control of *P. trivialis* and diuron resistant *P. annua*. Harvested seed yields were quantified and seed was assessed for percent germination. The preemergence herbicides, flufenacet/metribuzin, pyroxasulfone, pyroxasulfone/flumioxazin, indaziflam, s-metolachlor and dimethenamid-P controlled diuron resistant *P. annua* 90% or greater 29 days following application. *P. trivialis* was controlled greater than 90% with the exception of the indaziflam treatment which resulted in 85% control. In May, flufenacet/metribuzin treatments followed by a different herbicide provided control of 99-100% of *P. annua* and 94% or more of *P. trivialis*. A preemergence application of dimethenamid-P followed with flufenacet/metribuzin or indaziflam maintained control of both *Poa* species greater than 94% through May. Dimethenamid-P followed with s-metolachlor was equivalent to dimethenamid-P followed by pendimethalin for *P. annua* control, 90 and 91% respectively. For *P. trivialis* control, dimethenamid-P followed by metolachlor (79%) was better than dimethenamid-P followed by pendimethalin (60%). A preemergence s-metolachlor application followed by flufenacet/metribuzin, pyroxasulfone, indaziflam or dimetheamid-P maintained control of both species greater than 90% with the exception of *P. trivialis* control with dimethenamid-P (86%). *P. annua* control remained greater than 90% through May with a single application of flufenacet/metribuzin, pyroxasulfone, pyroxasulfone/flumioxazin, or indaziflam. *P. trivialis* control greater than 90% through May was achieved with indaziflam or pyroxasulfone/flumioxazin or utilizing a combination treatment of a preemergence application followed by a different herbicide. Of the currently registered herbicides in grasses grown for seed, the flufenacet/metribuzin preemergence treatment followed by pendimethalin is the only option that avoids using herbicides with the same mode of action. Indaziflam treatments resulted in the only injury rating and the injury was 10% or less. There were no differences in yields or percent germination in the harvested seed among treatments. Pyroxasulfone, pyroxasulfone/flumioxazin and indaziflam are not currently registered for use on grasses grown for seed. Pyroxasulfone/flumioxazin is in the IR-4 program for use in grasses grown for seed. Indaziflam appears to have utility in grass seed production and would introduce a new mode of action to the cropping system.

Expanding Uses for Pyroxasulfone: Pyroxasulfone and Pyroxasulfone + Flumioxazin Use in Peppermint Grown for Oil. Kyle C. Roerig*, Daniel W. Curtis, Andrew G. Hulting, Carol Mallory-Smith; Oregon State University, Corvallis, OR (134)

Peppermint is a crop grown primarily for its oil which is distilled from harvested peppermint hay and used as a flavoring. Weeds can reduce peppermint yield and negatively impact oil quality making weed control especially important in this crop. Pyroxasulfone is a relatively new preemergence Group 15 herbicide registered for use in corn, soybeans and wheat. Several years of our research indicate that pyroxasulfone can be used safely in established peppermint and may be safe in newly planted peppermint. Pyroxasulfone did not injure peppermint in 2011 or 2012 applied at 100 g ai/h at several timings from February, when peppermint is dormant, through June, when peppermint is large and growing rapidly. Flumioxazin is a Group 14 herbicide registered for use in peppermint that when applied to dormant, established peppermint does not cause lasting injury. Pyroxasulfone + flumioxazin is being marketed by Valent as Fierce™. Pyroxasulfone + flumioxazin applied to emerging newly planted peppermint at 160-200 g ai/h caused 63-70% injury in 2012 and 83% in 2013 when applied at 160 g ai/h. Pyroxasulfone applied at 100 g ai/h was safe on newly planted peppermint in February, May and June of 2012. In 2013, 321 g ai/h pyroxasulfone + flumioxazin controlled 100% of common groundsel, willowherb, prickly lettuce and sharp-point fluvellin without injuring established peppermint. In the same trial, pyroxasulfone alone applied at 202 g ai/h provided poor control of these weeds. Pyroxasulfone + flumioxazin applied at 202 g ai/h immediately following the first harvest of peppermint in 2013 controlled redroot pigweed in a double-cut production system. The combination of pyroxasulfone + flumioxazin greatly improves weed control compared with either active ingredient applied alone. Registration of pyroxasulfone and pyroxasulfone + flumioxazin for use in peppermint grown for oil production systems should be considered.

Weed Control and Grain Sorghum (*Sorghum bicolor*) Response to Postemergence Applications of Pendimethalin. Randall S. Currie*[1], Curtis Thompson[2]; [1]Kansas State Univ., Garden City, KS, [2]Kansas State, Mannhattan, KS (135)

Broadcast applications of pendimethalin in grain sorghum are currently not labeled for use on sorghum smaller than 4 inches in the High Plains. Work to possibly expand the label was reported in 2010 (Proc. NCWSS 65:120.) This work strongly suggested that pendimethalin applied at spike greatly enhanced grass control of other herbicide tank mixes and increased grain yield. To expand on this work, in 2013 studies were conducted at Garden City, KS and Tribune, KS to evaluate weed control and crop tolerance to 1X and 2X rates of pendimethalin applied at three postemergence timings. All treatments included preemergence applications of dimethenamid plus saflufenacil plus atrazine at 0.44 + 0.04 + 1.1 kg/ha followed by postemergence applications of 1.1 or 2.1 kg/ha pendimethalin applied to spike, 2-3 leaf or 12-inch sorghum. This experiment was conducted near Garden City, KS with populations of crabgrass, green foxtail and Palmer amaranth. It was repeated near Tribune, KS under weed free conditions. Experimental design was a randomized complete block with 4 four replications. Within 6 days of any herbicide application, 1 inch of overhead irrigation was applied to insure herbicide incorporation. Post applications of pendimethalin to spike and 2-3 leaf sorghum proceeded by preemergence saflufenacil and dimethenamid provided 3 fold better green foxtail and crabgrass control than the 12-inch timing, regardless of pendimethalin rate. All treatments produced significant levels of Palmer amaranth control compared to the untreated control. Although herbicide treatments were not statistically different, Palmer amaranth control with treatments of saflufenacil and dimethenamid followed by the highest rates of pendimethalin applied at spike and 2-3 leaf stage sorghum produced the highest levels of Palmer amaranth control. No visual above ground sorghum injury was observed at any location. At Tribune, root ratings taken 8 weeks after the last postemergence treatment showed no injury from labeled rates of pendimethalin. At twice the labeled rates of pendimethalin, the lowest level of root injury was seen with spike applications. The other application timings produced more than 2 fold higher levels of root injury. At Tribune, the highest pendimethalin rate resulted in significantly greater root injury (P=0.05) when applied at 2-3 leaf and 12 inch sorghum, but not at spike. These root ratings did not translate into yield reductions. There were no statistical reductions in yield at the 5% significant level. However, despite the lower levels of root ratings at the 10% significant level the spike applications of pendimethalin at twice the labeled rate reduced sorghum yield 15%. Clearly root ratings were not a good index of yield loss. Although possible injury from pendimethalin is confounded with weed control at the Garden City location, the highest yield was produced with the highest rate of pendimethalin applied at the 2-3 leaf stage. Further, lowest yielding treatments were measured with the latest application of pendimethalin regardless of rate. These treatments also had the poorest level of weed control. Although no visual injury was noted in these trials, in the previous study reported in 2010 the greatest level of injury was observed with this latest pendimethalin application. As was concluded in work done in 2010, this data also indicates that pendimethalin labels should be expanded to include earlier postemergence applications.

EnlistTM Corn Tolerance and Weed Control with PRE Followed by POST Herbicide Programs. Kristin Rosenbaum*[1], Joe Armstrong[2], Michael Moechnig[3], Scott C. Ditmarsen[4], Mark A. Peterson[5]; [1]Dow Agrosciences, Lincoln, NE, [2]Dow AgroSciences, Davenport, IA, [3]Dow AgroSciences, Toronto, SD, [4]Dow AgroSciences, Madison, WI, [5]Dow AgroSciences, Indianapolis, IN (136)

Enlist™ corn has been extensively evaluated in field research trials since 2006 and is anticipated to launch in 2015, subject to regulatory approvals. Enlist corn, stacked with SmartStax® technology, provides tolerance to both 2,4-D and glyphosate plus above- and below-ground insect resistance. Enlist Duo™ herbicide is a proprietary blend of 2,4-D choline and glyphosate dimethylamine (DMA) that is being developed by Dow AgroSciences for use on Enlist crops. Dow AgroSciences will be recommending the use of soil residual herbicides as a part of the Enlist™ Weed Control System to provide early season weed control and crop yield protection along with additional modes of action to proactively manage weed resistance.

Field research trials were conducted in 2013 to evaluate herbicide programs involving Enlist Duo and SureStart® herbicide (acetochlor + clopyralid + flumetsulam) for weed control and crop tolerance. Treatments consisted of weed management systems utilizing SureStart applied preemergence (PRE) followed by a postemergence (POST) application of Enlist Duo to V4 corn, SureStart + Enlist Duo applied early POST to V2 corn, or SureStart + Enlist Duo applied POST to V4 corn. The rate of Enlist Duo™ in the POST applications was 1640 g ae/ha. The PRE rate of SureStart varied by soil type (1019-1747 g ae/ha) and the POST rate was 1170 g ae/ha. At 28 days after the V4 application timing, SureStart PRE followed by Enlist Duo POST provided >95% control of glyphosate-resistant waterhemp, common ragweed, and giant ragweed. POST applications of SureStart + Enlist Duo at V2 or V4 also provided >95% control of glyphosate-resistant species.

Crop tolerance ratings were taken at 7 and 14 days after the V2 and V4 applications. Visual injury with SureStart® applied PRE followed by Enlist Duo at V4 averaged 1% at 7 and 14 days after V4 application. The tank mix of SureStart + Enlist Duo at V2 resulted in an average of 3% and <1%

injury at 7 and 14 days after application, respectively. Applications of SureStart + Enlist Duo at the V4 growth stage resulted in 3 and 2% injury at 7 and 14 days after application, respectively.

Residual herbicides provide an effective means to prevent yield loss caused by early season weed competition and bring additional modes of action to the weed control program as a component of weed resistance management best practices. These trials demonstrate the utility of residual herbicides followed by POST applications of 2,4-D choline + glyphosate DMA as part of the Enlist Weed Control System in Enlist corn.

Bicyclopyrone, a New Herbicide for Improved Weed Control in Corn. Peter C. Forster*[1], Thomas H. Beckett[2], Scott E. Cully[3], John P. Foresman[2], Ryan D. Lins[4], Gordon D. Vail[2]; [1]Syngenta Crop Protection, Eaton, CO, [2]Syngenta Crop Protection, Greensboro, NC, [3]Syngenta Crop Protection, Marion, IL, [4]Syngenta Crop Protection, Byron, MN (137)

Bicyclopyrone is a new selective herbicide for weed control in field corn, seed corn, popcorn and sweet corn. The bicyclopyrone mode of action is inhibition of HPPD (4-hydroxyphenyl-pyruvate dioxygenase) enzyme which ultimately causes the destruction of chlorophyll followed by death in sensitive plants. Upon registration, SYN-A197 will be the first bicyclopyrone containing product launched with anticipated first commercial application in the 2015 growing season. SYN-A197 is a multiple mode-of-action herbicide premix that provides preemergence and postemergence grass and broadleaf weed control. Field trials were conducted to evaluate SYN-A197 for weed control and crop tolerance compared to commercial standards. Results show that SYN-A197 very effectively controls many difficult weeds and provides improved residual control and consistency compared to the commercial standards.

PROJECT 4: TEACHING AND TECHNOLOGY TRANSFER

Recommended Spray Droplet Sizes, Spray Volumes and Drift Reduction Technology. Robert N. Klein*; University of Nebraska, North Platte, NE (107)

It is estimated that 1 to more than10% of pesticide drifts from the application site. Drift is of concern because it takes the pesticide from the intended target, making it less effective, and deposits it where it is neither needed nor wanted. The pesticide then becomes an environmental pollutant in the off target areas where it can injure susceptible vegetation, contaminate water or damage wildlife. Drift cannot be eliminated, but the use of proper equipment, additives and application procedures will maintain the spray drift deposits within acceptable limits. While not currently required, it is expected that EPA may soon be suggesting (or requiring) the use of validated drift reduction technology (DRT) to further reduce spray drift. Factors which influence spray drift include wind, boom height, and distance from susceptible vegetation and spray particle size. Spray particle size is affected by nozzle type, spray pressure, pesticide, carrier, additives and weather conditions. Charts have been developed for 3 spray particle sizes at 93.4 and 186.8 L/ha, for glyphosate at 93.4 L/ha and fungicide and insecticide at 140.1 and 186.8 L/ha. These have been developed using TeeJet nozzles at speeds from 9.66 to 22.54 Km/hour and nozzle spacing of 38.1, 50.8 and 76.2 centimeters. These charts all are based on spraying water and included in the 2014 Nebraska Weed Management Guide. The plan in the future includes charts on how the pesticide and additives affect spray particle size.

Development of a Calibration App for Smartphones. Guy B. Kyser*, Joseph M. DiTomaso; University of California, Davis, CA (108)

Calibration of herbicide application equipment helps to ensure application of correct rates. Precise applications provide optimal efficacy and selectivity while minimizing non-target damage and unnecessary costs. However, the typical applicator who makes only a few applications each year tends to avoid calibrating and has no incentive to invest in precision equipment such as sprayer controllers. We frequently teach calibration at growers' meetings, but this can be difficult: we must either describe a confusing series of calculations, or present an arcane 'cookbook' method. To simplify the process, we are developing a smartphone app to assist in calibration of both broadcast and directed pesticide applications. The app guides the user through measurement of calibration variables and uses these values to calculate application information. For example, spray volume in a broadcast treatment is determined by output rate, spray width, and application speed. The app prompts the user to collect spray output while pressing start/stop buttons on the app's timer. Given nozzle number and spacing, the app calculates swath width. And the app uses the phone's clock and GPS to measure speed during a test run. Given these three factors, the app calculates and displays the total spray volume. Once the user enters the size of the spray tank and the rate of material(s) to be applied, the app calculates the treatable area and the amount of material to put in the tank. All values can be entered or output in either English or metric units. We intend to make this app available at no cost.

Advancing Herbicide Resistance Management: Bringing in New Perspectives. Jill Schroeder*[1], David Shaw[2], Micheal D. Owen[3], Harold Coble[4], John Soteres[5], Amy Asmus[6], Blaine Viator[7], George Frisvold[8], Raymond Jussaume[9], Kara Laney[10], Robin Schoen[10], David Ervin[11], Terrance Hurley[12]; [1]New Mexico State University, Las Cruces, NM, [2]Mississippi State University, Starkville, MS, [3]Iowa State University, Ames, IA, [4]USDA, Washington, DC, [5]Monsanto, St. Louis, MO, [6]Asmus Farm Supply, Inc, Ames, IA, [7]Calvin Viator, Ph.D. and Associates, LLC, LA, [8]University of Arizona, Tucson, AZ, [9]Michigan State University, East Lansing, MI, [10]National Academy of Science, Washington, DC, [11]Portland State University, Portland, OR, [12]University of Minnesota, St. Paul, MN (109)

The evolution of an increasing number of herbicide-resistant weed species has become a major concern across U.S. agriculture, particularly in crop production systems that depend on the widespread use of a limited number of weed management practices and because no new herbicide mechanisms of action have been commercialized for 25 years. The scientific community has expressed concern that the ability to manage weeds in production agriculture will decrease if an integrated system of best management practices for herbicide resistance prevention and mitigation is not implemented. In May 2012, a number of organizations, with support from a USDA AFRI conference grant, sponsored a National Herbicide Resistance Summit which was hosted by the National Research Council in Washington, DC (http://nas-sites.org/hr-weeds-summit/). Rather than an end-point, the first Herbicide Resistance Management Summit was viewed as a starting point and call for action. While the need for continued research on the biology and ecology of herbicide resistant weeds to develop diversified management strategies was recognized, the summit participants highlighted the need to understand the socio-economic forces and other competing agendas that conflict with grower management decisions to address herbicide resistance. Furthermore, engagement of all stakeholders will be needed to bridge the biological, economic, regulatory, human, and community dimensions of the problem and identify the most important decision drivers that impact weed management across different crop production settings and ecosystems. The results of this dialog will be an understanding of how best to approach effective weed management planning from all who contribute to these decisions, including growers, land managers, retailers, applicators, agrichemical industry, university research and extension, crop advisors, state and federal agencies, environmental groups, and others. To further the discussion and development of action plans, a workshop for stakeholders representing these groups was held in September 2013. The goal of this workshop was to listen to all participants, identify the challenges in herbicide resistance management, and brainstorm to develop action plans that reduce the adverse effects of weeds and weed resistance in production agriculture. The ideas that emerged from the workshop included a need to: 1) understand motivations for decisions at the farm level, 2) tell the economic story, 3) have a central location to house the information and tools required for developing resistance management plans in order to remove confusion over mixed messages going out to decision makers, 4) provide education and outreach training for absentee landowners, land managers, lenders, and others who impact decisions but have not been reached with current education and outreach programs, 5) use incentive programs to promote more rapid and widespread adoption of resistance management as well as reform rental agreements and regulatory programs to minimize disincentives that currently discourage resistance management, 6) invent sustainable community-based approaches to management that are able to adapt to individual and regional heterogeneity, 7) develop new technologies including sprayers, tillage, robotics and technologies to facilitate sprayer and combine cleanout and can make resistance management simpler and more convenient for growers, and 8) adopt clear mechanism of action labeling to support best management practices for all herbicides. The planning committee continues to meet to address the action items identified by workshop participants and to plan for a second national summit on herbicide resistance in September 2014. Progress to date and a discussion of what remains to be done will be presented for each of these major topics. The goal of the second summit will be for every attendee to walk away with a clear understanding of their role in solving this difficult problem and their commitment to fulfill this role.

PROJECT 5: BASIC BIOLOGY AND ECOLOGY

Evolution of Glyphosate Resistance in Kochia. Phillip W. Stahlman*[1], Amar S. Godar[2]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Manhattan, KS (116)

Glyphosate resistance in kochia (*Kochia scoparia*) was first confirmed in four populations in western Kansas in 2007 and eight additional populations were confirmed resistant to glyphosate in 2010. Lack of kochia control with glyphosate was common throughout western Kansas and far eastern Colorado in 2011. These events suggested that kochia populations in the region were in different stages of evolutionary development. Plants from seed collected in 2012 from 34 kochia populations throughout western Kansas, three populations from the Oklahoma Panhandle, two populations from eastern South Dakota, and one population from southern Idaho were sprayed in repeated experiments with 840 g ae ha^{-1} glyphosate (72 total plants per population) to compare population susceptibility to glyphosate. *In vivo* shikimate accumulation was determined on nine plants per population prior to glyphosate treatment. Kochia populations showed varied response to glyphosate 18 d after treatment, ranging from 0 to 100% mortality. A majority of plants in 15 of 40 populations including one South Dakota and two Oklahoma populations were injured ≤60% and another 10 populations exhibited greater than ≥60% injury but survived. Only in five populations did most plants die from glyphosate treatment. The results indicated that kochia populations were at different stages of evolved resistance to glyphosate. Plants exhibiting greater injury (susceptibility) accumulated more shikimate in glyphosate-treated (100 µM) leaf discs after 16 h than lesser injured plants (R^2 = 0.79, $P<0.01$). However, there was no clear relationship between plant response and shikimate accumulation in populations injured ≥60%. Relationships among mortality, injury, and frequency of plants with ≤30% injury indicate evolutionary processes occur both at individual plant and population levels. It can be expected that continued selection will drive evolution towards resistance.

Comparison of the Eco-Efficiency of Conventional and Glyphosate-Resistant Sugarbeet Herbicide Treatments. Carl W. Coburn*, Andrew R. Kniss; University of Wyoming, Laramie, WY (117)

The introduction of glyphosate-resistant sugarbeet has greatly altered sugarbeet production practices. These changes have the potential to impact the environment either positively or negatively, but environmental impact can be difficult to quantify. Eco-efficiency analysis is a method to compare production methods by quantifying the output produced per unit of environmental impact of the inputs used. Eco-efficiency analysis was used to compare the environmental impact of conventional and glyphosate-resistant sugarbeet production from published studies. Risk quotients were calculated based on herbicide exposure potential and toxicity to various environmental indicators to provide an estimate of environmental impact. Environmental indicators included avian, mammalian, honeybee, aquatic (invertebrate and vertebrate), and groundwater risk. Yield was divided by treatment risk quotient to determine treatment eco-efficiency. Risk from the use of all herbicides was below EPA established limits. Eco-efficiency for glyphosate treatments was similar to, or greater than, all conventional herbicide treatments for all environmental indicators with the exception of micro-rate treatments for the terrestrial indicators. Overall, the conversion from conventional sugarbeet herbicides to glyphosate in glyphosate-resistant sugarbeet has resulted in a net benefit for herbicide environmental impact per unit sugar yield.

The Biology and Evolution of Glyphosate Resistant Kochia in North America. Philip Westra*[1], Hugh Beckie[2], Linda Hall[3]; [1]Colorado State University, Ft. Collins, CO, [2]Ag Canada, Saskatoon, SK,[3]University of Alberta, Edmonton, AB (118)

Kochia populations that survive labeled field rates of glyphosate have been documented in TX, OK, KS, CO, NE, SD, ND, MT, Alberta, Saskatchewan, and Manitoba. These populations are frequently identified by growers, crop consultants, and extension personnel as "green streaks or trails" of surviving plants in fallow or crop fields where all other kochia plants are well controlled. These trails result from glyphosate resistant mother plants that blow across the landscape in the fall, dropping seeds as they bounce on the ground. Greenhouse dose response studies frequently show that most such populations collected in the field either as plants or as seeds are still segregating for the level of glyphosate resistance, but some will survive up to 6 kg/ha of glyphosate in greenhouse studies. Resistance due to differential glyphosate uptake and translocation has largely been eliminated as the mechanism of resistance. EPSPS sequencing reveals no mutations known to confer glyphosate resistance in other plant species. Molecular and genomic research, however, has shown that all glyphosate resistant kochia plants evaluated to date do exhibit EPSPS gene amplification, similar to what was documented in Palmer amaranth by Gaines et al., although the gene copy number is much lower (3 to 11 copies) than was observed in Palmer amaranth (up to 200 copies). It seems clear that 3 copies are sufficient to provide resistance to field rates of glyphosate. To address an obvious gene evolutionary question, we intend to collect resistant populations over multiple years to determine if EPSPS gene copy number increases to a higher level over time. In 2014, we will use RNAseq and multiple probed gene sequences to evaluate the genetic relatedness of glyphosate resistant kochia from TX to Canada. Transcriptome sequence of glyphosate-resistant and –susceptible kochia RNA yielded over 16,000 high quality contigs and demonstrated that of the key enzymes involved in the corismate pathway, only EPSPS is significantly up regulated in glyphosate resistant kochia plants. The tumbleweed biology of kochia presents a unique and powerful method for the rapid spread of the glyphosate resistant trait across the landscape. A coordinated regional effort to conduct kochia research over the next several years is emerging from the collaborative research being conducted at the field, lab, and molecular level with kochia. This collaboration will include new 2014 research projects among researchers from the US and Canada. Plans are underway to obtain the full genome sequence of kochia in hopes of being able to extract beneficial genes that might confer novel drought, heat, cold, and salt tolerance in agronomic crops.

Effects of Colored Mulch on Beta vulgaris Growth. Thomas J. Schambow*, Andrew R. Kniss, David A. Claypool; University of Wyoming, Laramie, WY (119)

Plants use different wavelengths of light to most effectively photosynthesize. Both the red spectrum (622-780 nm) and blue spectrum (455-492 nm) are used to photosynthesize most efficiently, while the green spectrum (492-577 nm) is reflected and minimally used by plants. Experiments were conducted on three varieties of *Beta vulgaris*—sugarbeet, table beet and Swiss chard—to determine if five different colored plastic mulches surrounding plants grown in five gallon pales would increase both growth and yield. It was hypothesized reflected colored light may be used by plants, or trigger physiological responses (such as shade avoidance). The study was a factoral treatment arrangement in a randomized complete block design. Factors included *Beta vulgaris* variety and plastic mulch color. Leaf counts and growth stages were taken from emergence to harvest, as well as a range of harvest measurements. Differences were observed between *Beta vulgaris* varieties. Mean leaf area in sugarbeet was 16100 cm^2, Swiss chard was 15860 cm^2 and table beet was 14280 cm^2. Plastic mulch color had no significant effect on growth and yield measurements. This conflicts with some previous research, which indicated certain mulch colors might increase beet root weight. These results suggest that increasing reflected colors of light through the use of plastic mulch may not significantly affect growth and yield of *Beta vulgaris*.

Impact of Seedbank Life on Kochia Population Dynamics. Anita Dille*[1], Andrew R. Esser[1], Phillip W. Stahlman[2], Phil Westra[3], Andrew R. Kniss[4], Robert G. Wilson[5], Randall S. Currie[6]; [1]Kansas State University, Manhattan, KS, [2]Kansas State University, Hays, KS, [3]Colorado State University, Fort Collins, CO, [4]University of Wyoming, Laramie, WY, [5]University of Nebraska-Lincoln, Scottsbluff, NE,[6]Kansas State Univ., Garden City, KS (120)

Population dynamics of a weed species describes the change in individuals, such as seed in the soil seedbank, through time. It can be described using a lifecycle model that includes states and transitions. States include individuals that can be counted, such as seed, seedlings, and flowering adults. Transitions include the proportion of individuals that change from seed to become seedlings, and the number of seedlings that survive to become flowering adults, and seed production. Kochia continues to be a very significant threat to cropping systems in the central Great Plains. Several field experiments were conducted between 2010 and 2013 across this region. One set of experiments determined the total emergence and patterns of emergence in cropland and non-cropland environments during the spring of 2010 and 2011 at multiple sites in Colorado, Kansas, Nebraska, and Wyoming. Quadrats were marked in which weekly observations of emergence were documented by counting and removing emerged seedlings. The next set of experiments took kochia seed harvested from each site in 2010 and 2011 to determine the length of time that seed persisted and was viable when placed at different depths in the seedbank at each site. Packets of 100-seed were buried in December at 0, 2.5 and 10 cm depths and were extracted the following March and October for two years. Seed from extracted packets were placed in petri dishes in a growth chamber to evaluate seed viability. Total seedling population densities varied among locations and ranged from as few as 10 to almost 332,000 seedlings / m^2. When seed densities were very large, emergence was early and rapid, such that the slope of cumulative emergence was very steep in contrast to when seed densities were less, the length of time to reach total cumulative emergence was much slower. After seed rain, viability of kochia seed remains great no matter whether it was deposited on the soil surface or buried 10 cm deep. At the Nebraska sites, seed viability in March approximately 4 to 5 months after seed rain, ranged between 80 to 95% viable seed, but by October, 10 to 11 months later, seed viability ranged between 0 and 2%, and after two years was less than 1.25%. So why does kochia continue to be a significant weed issue with such short seedbank life? Seed produced on plants growing with sibling plants produces a variety of seed with increased levels of dormancy (15% of seed) compared to sparse plants growing beneath crop canopies that produce 1 to 3 % dormant seed. These dormant seed move into the seedbank and help the population persist to future years.

Mature Seed Set Variation among PNW *Bromus tectorum* Accessions. Nevin Lawrence*[1], Ian C. Burke[1], Daniel A. Ball[2]; [1]Washington State University, Pullman, WA, [2]Oregon State University, Pendleton, OR (121)

A previously published downy brome development model investigated the mature seed set of four downy brome accessions collected from the Pacific Northwest (PNW) and identified 1,000 growing degree days (GDD) as a relevant development threshold for the region. To validate and add greater spatial resolution to the previously published downy brome development model, ninety-five downy brome accessions were collected from within the small grain production area of the PNW during 2010 and 2011. In November of 2012, accessions were transplanted as seedlings into a common garden located near Central Ferry, WA. Following the first observation of flowering, the most mature panicle of each individual was removed each week until the conclusion of the experiment. GDD were calculated for each harvest date. The seed was allowed to after ripen for three months and panicles were tested for seed maturity in a greenhouse experiment. Sampled panicles were planted using a separate RCBD for each harvest date with six replicates per accession. Germination after two weeks was reported as a binary response. Non-linear regression was used to estimate the date of mature seed production by fitting a two-parameter loglogistic model for each accession and estimating the GDD at which 5% germination occurs. The average GDD estimate for all accessions for 5% germination was 1114 GDD and ranged 930 to 1358 GDD. The distribution of downy brome accessions is spatially significant with early maturing accessions found predominantly in the Western production region of the PNW.

Using an in vivo Shikimate Accumulation Assay to Determine Glyphosate Sequestration in Glyphosate-Resistant Plants. Jamshid Ashigh*[1], Mohsen Mohseni-Moghadam[2], Brian J. Schutte[3], Anil Shrestha[4];[1]Extension Weed Specialist/Assistant Professor, Las Cruces, NM, [2]Ohio State University, Wooster, OH, [3]New Mexico State University, Las Cruces, NM, [4]California State Fresno, Fresno, CA (122)

The objectives of this study were to investigate the possibility of using an adjusted *in vivo* shikimate accumulation assay in determining glyphosate sequestration in glyphosate-resistant (GR) plants, and to determine whether glyphosate sequestration is an additional mechanism of resistance in GR Palmer amaranth populations from New Mexico. Quantitative real-time PCR analysis indicated up to an 8-fold increase in genomic *EPSPS* copy number in GR Palmer amaranth plants compared with susceptible (GS) plants from New Mexico. The number of gene copies in GR Palmer amaranth populations from NM contradicts the suggestion that between 30 and 50 *EPSPS* genomic copies are necessary to survive glyphosate field dose. *In vivo* shikimate accumulation assays with and without the addition of glycine were conducted in this study. The addition of different concentrations of glycine in wells of microtiter plates with excised leaf tissues of GR plants increased the shikimate concentrations compared with wells without glycine. The accumulation of shikimate was dependent on the level of resistance in the GR Palmer amaranth plants, previously determined to be correlated with the number of *EPSPS* copies. The precision of this assay was also tested and confirmed with horseweed (*Conyza canadensis*) plants from California that were previously confirmed to be GR due to glyphosate sequestration. The adjusted *in vivo* shikimate accumulation assay in this study seems to be a promising method for rapid detection of glyphosate sequestration as a mechanism of resistance in GR plants. Furthermore, our results suggest that the mechanism of glyphosate resistance in Palmer amaranth populations from NM is both *EPSPS* amplification and glyphosate sequestration.

Greenhouse Dose Response to Aminocyclopyrachlor on Honeylocust, Green Ash, Norway Spruce and Blue Spruce Trees in Colorado. Curtis M. Hildebrandt*, Phil Westra; Colorado State University, Fort Collins, CO (123)

Aminocyclopyrachlor (AMCP) is a selective pyrimidine carboxylic acid herbicide with significant soil residual activity. The water solubility of AMCP and its soil residual activity may impact bioavailability to non-target tree species. To date, commercial use of AMCP has shown variable tree species response. In April of 2013, a greenhouse dose response study was established to determine relative sensitivities of four different tree species to AMCP: green ash, honeylocust, blue spruce, and Norway spruce. Bare-root whips of the four species were planted into pre-treated soil containing the following treatments: 0, 0.625, 1.276, 2.526, 5.051, 10.102, 20.205, and 40.41 ppb. Visual rating and height data were collected 30 and 60 days after treatment (DAT). Analysis of visual rating data from the dose response study 60 DAT indicated that green ash was the most tolerant species, followed by honeylocust, then blue spruce, and then Norway spruce which was the most sensitive species. Results will be used to help establish label guidelines for AMCP use where desirable tree vegetation exists. Future dose response studies will capture a larger range of treatment rates, as well as longer study duration.

Metabolism-Based Diclofop Resistance in Lolium rigidum: Using RNA-Seq Transcriptome Analysis to Identify Resistance-Endowing Genes. Todd A. Gaines*[1], Lothar Lorentz[2], Roberto Busi[3], Heping Han[3], Qin Yu[3], Stephen Powles[3], Roland Beffa[2]; [1]Colorado State University, Fort Collins, CO, [2]Bayer CropScience, Frankfurt am Main, Germany, [3]University of Western Australia, Crawley, Australia (124)

Weed control failures due to herbicide resistance are an increasing and worldwide problem significantly impacting crop yields. Metabolic herbicide resistance in weeds is not well characterized at the genetic level. An RNA-Seq transcriptome analysis was used to find candidate genes conferring metabolic resistance to the grass herbicide diclofop in a population (R) of the major global weed *Lolium rigidum*. A reference cDNA transcriptome of 19,623 contigs was assembled and annotated. Global gene expression was measured using Illumina 100 bp reads from untreated control, adjuvant-only control, and diclofop treatment of R and susceptible (S). Contigs showing constitutive expression differences between untreated R and untreated S were selected for further validation analysis, including 11 contigs putatively annotated as cytochrome P450 (CytP450), glutathione transferase (GST), or glucosyltransferase (GT), and 17 additional contigs with annotations related to metabolism or signal transduction. In a forward genetics validation experiment, nine contigs had constitutively higher expression in R individuals from a segregating F_2 population, including 3 CytP450, one nitronate monooxygenase (NMO), 3 GST, and 1 GT. Cluster analysis using these nine contigs differentiated F_2-R from F_2-S individuals. In a physiological validation experiment where 2,4-D pre-treatment induced diclofop protection in S individuals due to increased metabolism, seven of the nine genetically-validated contigs were significantly induced. Four contigs (2 CytP450, NMO, and GT) were consistently highly expressed in nine field-evolved metabolic resistant *L. rigidum* populations. These four genes were strongly associated with the resistance phenotype and are major candidates for contributing to metabolic diclofop resistance.

Influence of Soil Properties and Soil Moisture on Indaziflam Efficacy. Derek J. Sebastian*, Phil Westra, Scott J. Nissen; Colorado State University, Fort Collins, CO (125)

Indaziflam is a new alkylazine herbicide used for broad spectrum pre-emergence control of over 75 grass, broadleaf, and annual sedge species. The objective of these experiments was to determine how soil moisture and herbicide sorption influence herbicide efficacy. Batch-equilibria sorption studies were conducted to determine indaziflam K_d values in 28 soils, representing a wide range of physical and chemical properties. Sorption values ranged from 0.6 to 88.5 and were found to be positively correlated with soil organic matter (r = 0.708) and percent silt (r = 0.547), and negatively correlated with percent sand (r = -0.453) and pH (r = -0.554). To assess influence of soil moisture, nine soils were selected based on differing physical properties and soil-water retention curves were generated for each using a pressure plate apparatus. The effect of soil moisture on indaziflam and flumioxazin efficacy was determined using kochia (*Kochia scoparia)* as the indicator species. Kochia GR_{80} values were generated for each soil at field capacity. These herbicide rates were incorporated in each soil over a range of soil moisture tensions from 0.1 to 4 bars. Kochia growth was represented as growth reduction compared to an untreated control. Indaziflam and flumioxazin biological activity decreased as soil moisture decreased. These findings can be used to understand indaziflam performance in environments with low soil moisture where sufficient moisture is present to allow germination but not enough for herbicide activation. The sorption data may be applied to field soils from throughout the country with similar physical and chemical properties, to better understand indaziflam performance and rates required for effective control of kochia.

Pre-Harvest Herbicide Effects on Hairy Fleabane Seed Production. Lynn M. Sosnoskie*[1], Bradley D. Hanson[2]; [1]University of California - Davis, Davis, CA, [2]University of California, Davis, CA (126)

Weed pressure, and the resulting competition for water and nutrients, can significantly impact crop establishment, growth, and harvest/yield. Furthermore, there is some concern among growers that non-managed weeds may support populations of insect, vertebrate, and pathogenic pests that can significantly reduce crop health. Unfortunately, complete weed control is not always assured, regardless of management strategy. Weed escapes can occur for numerous reasons including: improper herbicide selection or inappropriate timing of chemical applications, unfavorable weather conditions, and the development of herbicide resistance in the target weed population.

Glyphosate is the predominant herbicide in many of California’s high-value specialty crops. In 2011, greater than 90% of all bearing tree and vine acreage in the state was treated, at least once, with glyphosate; moreover, glyphosate was applied to more tree nut, stone fruit and grape vine acres than the second (oxyfluorfen (Goal 2XL, GoalTender)) and third (glufosinate (Rely 280)) most common active ingredients, combined. This reliance on glyphosate has not come without consequences; currently, resistance to glyphosate has been confirmed in rigid ryegrass (*Lolium* *rigidum*), Italian ryegrass (*Lolium multiflorum*), junglerice (*Echinochloa colona*), horseweed (*Conyza canadensis)* and hairy fleabane (*Conyza bonariensis*).

Numerous authors have described the consequences of weed control failures. Weedy plants that escape control measures often have the potential to reach reproductive maturity and set seed, which could replenish or enhance the seedbank. Results from previously conducted studies have demonstrated that herbicide resistance response in *Conyza* species can vary significantly, within biotypes, due to plant size/developmental stage at the time of treatment. Late-season, pre-harvest herbicide applications can and do occur when growers delay treatments in order to maximize weed emergence/minimize the frequency of control efforts.

In 2012 and 2013, four non-selective, POST herbicides (glyphosate, paraquat, glufosinate and saflufenacil) were applied at labeled rates to susceptible, glyphosate-resistant, and glyphosate/paraquat-resistant hairy fleabane plants at one of three stages of development (mature rosette/bolting, budding, and the first appearance of flower buds). Plant injury, height and flower/seedhead production were evaluated, weekly, for 9 (2012) and 11 (2013) weeks following application, at which time biomass measurements were taken.

Glyphosate-susceptible hairy fleabane height at nine weeks after treatment was reduced 95-100%, relative to the untreated check, by all herbicides when applications were made to mature rosettes. Except for the paraquat treatment (59% reduction in height, similar results were observed for plants that were treated at the budding stage (93-100% reduction in height). Mean plant height was not significantly reduced when glyphosate-susceptible plants were treated at the flowering stage (Plants were 75-90% as tall as the controls at 9-11 weeks after treatment). Resistant (glyphosate and glyphosate/paraquat) plants were also most susceptible to herbicide applications when plants were treated at smaller/younger growth/developmental stages. Late rosette and budded plants were 18-35% (glyphosate), 90-100% (glufosinate), 43-48% (paraquat) and 100% (saflufenacil) smaller than the untreated checks at nine weeks after treatment. Plants that were treated while they were flowering were between 15 and 30% smaller than the controls.

Cumulative reproductive output, for both susceptible and resistant plants, was significantly influenced by growth stage and herbicide. Results show that larger and more mature glyphosate-susceptible hairy fleabane plants were best able to produce flower buds, flowers and seed heads following non-fatal herbicide applications. For example, in 2012, glyphosate- and glyphosate-paraquat-resistant plants treated at the bolted and budded stages produced fewer than 200 mature seed heads, flowers and flower buds per plant; plants that were treated while they were flowering produced, on average, 320 per plant. With respect to herbicide, all of the tested products significantly reduced total reproductive output, relative to the untreated check, by more than 50%.

In addition to achieving intra-seasonal goals (e.g. weed control, crop yield preservation), the success of a weed management program can be evaluated according to how well it alters the trajectories of weed populations over time. Although this data shows that non-fatal, late-season weed management strategies resulted in reduced reproductive output hairy fleabane, it also demonstrates that viable seed could be produced and returned to the local seedbank following a weed control failure. With respect to herbicide resistance, incomplete weed control allows for the retention of the resistance trait within a weed population, which can have multi-season ramifications for weed control. Traditional IPM recommendations encourage growers to prevent weeds from setting seed in order to reduce the size of the local seedbank and prevent the establishment and spread of advantageous (for the weed) attributes (such as herbicide resistance).

Predicting Buffelgrass Herbicide Susceptibility Using Antecedent Weather and Ground-Based Remote Sensing. Travis M. Bean*, Steven E. Smith; University of Arizona, Tucson, AZ (127)

Buffelgrass is a perennial C_4 bunchgrass that is invasive in subtropical regions worldwide. Control of buffelgrass has become a priority in many areas because of its rapid invasion rate, tendency to displace native vegetation, and the associated fire risk to native plant communities, adjacent developed areas and their associated infrastructure. Because of the high growth rate often seen in buffelgrass populations and the high cost of large-scale mechanical control, chemical control currently offers the most promise for successful management on a regional scale. The predominant herbicide used to control buffelgrass is glyphosate, which requires active vegetative growth when applied for optimum translocation to meristematic tissue. However, control efforts are confounded by manager's inability to accurately predict the occurrence and duration of active growth periods. Our objective is to predict the timing and length of active growth based on antecedent weather for a given location and season. This will allow herbicide application efforts to be directed to time periods and sites where plants are most susceptible. We have evaluated relationships among temperature, precipitation, and soil moisture, and various measures of vegetative growth including tiller moisture content, and plant size and greenness using daily photographs of buffelgrass at three sites in the Tucson Basin. We present data from the summer 2012 and 2013 growing seasons to provide an example of modeled versus actual plant greenness and discuss management implications of our findings.

EDUCATION & REGULATORY SECTION

Using the R Statistical Language to Analyze Agricultural Experiments. Andrew R. Kniss*; University of Wyoming, Laramie, WY (110)

Group Discussion of R and How WSWS Members Are Using It.

SYMPOSIUM: Biology and Management of Invasive Toadflax in the Western US

Introducing the Culprits: Invasive Toadflax in the Western U.S. Sarah M. Ward*; Colorado State University, Fort Collins, CO (111)

Yellow toadflax (*Linaria vulgaris* Mill.) and Dalmatian toadflax (*L. dalmatica* (L.) Mill.) are perennial forbs belonging to the Scrophulariaceae. Yellow toadflax was introduced to the eastern U.S. by colonists from northern Europe in the late 1600s and is now widespread, possibly representing the earliest recorded exotic plant invasion in North America. Dalmatian toadflax is native to the Mediterranean region and was first reported as naturalizing in the western U.S. in the late 1800s, apparently after multiple introductions of this plant by humans. Both species are genetically diverse insect-pollinated outcrossers, a suite of traits that increases their adaptive potential in a novel range. Yellow toadflax and Dalmatian toadflax are currently listed as noxious invasive weeds of forest and rangeland in multiple western states, where they present significant management challenges.

Variable Response of Yellow Toadflax to Herbicides. George Beck*, James R. Sebastian; Colorado State University, Fort Collins, CO (112)

Yellow toadflax (*Linaria vulgaris*) is an invasive weed and very problematic in several western states. It occurs throughout the U.S. but is only considered noxious in the west (CO, ID, MT, NM, OR, SD, WA, and WY). We have explored the activity of many herbicides over the past 28 years in Colorado and the only thing consistent was site to site and year to year variation in control. We examined, picloram, fluroxypyr, dicamba, dicamba + diflufenzopyr, 2,4-D, glyphosate, imazapyr, imazapic, metsulfuron, chlorsulfuron, and aminocyclopyrachlor. Only picloram, chlorsulfuron, and imazapyr displayed good activity but rarely did we ever observe 100% control 1 year after treatment (YAT) or longer. One study started in 2007 evaluated picloram with and without diflufenzopyr + dicamba (Overdrive). Picloram at 8 oz ai/A + 0.8 oz ai diflufenzopyr + 2 oz ai dicamba (4 oz Overdrive) applied at late flower controlled 97 and 98% of yellow toadflax 1 and 2 YAT, respectively – the best control to date from a selective treatment. A MS student project showed, however, the importance of rate and application timing to effect optimal control of yellow toadflax. At five Colorado sites, chlorsulfuron was applied at 0, 0.6, 0.9, and 1.3 oz ai/A plus a methylated seed oil (1.5 pt/A) over a 10-day period in September 2009. Growth rate varied somewhat from site to site. Control at two of the sites (Camp Hale and Hot Sulphur Spring) was 93 and 99%, respectively, 2 YAT from the 1.3 oz rate. Control at the remaining sites was 87, 73, and 68% and these latter three means were statistically less than at Camp Hale and Hot Sulphur Springs. The two key elements were herbicide rate and timing. At Camp Hale, 65% of the shoots were post flower/seed capsule growth stages and only 17% still vegetative and at Hot Sulphur Springs, 48% of shoots were post flower/seed capsule growth stages and 24% vegetative. The Greenland site had only 8% of shoots in post flower, 47% vegetative; White River 35% post flower, 41% vegetative; Wildcat Canyon 15% post flower, 25% vegetative but this site was droughty in 2009. The post flower/seed capsule growth stages coincided with peak adventitious crown and root bud growth in a separate study and it is likely that yellow toadflax at Camp Hale and Hot Sulphur Springs were in this peak adventitious crown and root bud stage at application in 2009 and better control ensued.

Invasiveness of Dalmatian Toadflax in Mountain Ecosystems. Lisa J. Rew*, Fredric W. Pollnac; Montana State University, Bozeman, MT (113)

Mountainous areas cover a relatively small portion of the land surface of the earth, but contain a large portion of terrestrial plant diversity and endemic plant species richness. Climate change and increased use by humans at higher elevations both have the potential to increase the presence of non-indigenous plant species (NIS) in mountainous areas. To understand current distributions and be able to make predictions for the future we evaluated *opportunity* (chance of seed reaching a site) and *ability* (chance of seed establishing and reproducing). We studied Dalmatian toadflax (*Linaria dalmatica*) populations along mountain roads in the Greater Yellowstone Ecosystem over a period of five years. Dalmatian toadflax showed increased overall seed production at high elevation limits, suggesting that this opportunity limitation is absent. The NIS showed positive associations between elevation and stem density, and models including climatic and biotic/edaphic environmental variables resulted in decreased Bayesian Information Criterion (BIC) values. The increase in stem density was closely tied to increased snowpack at higher elevations in the late spring, and it appeared to broadly adapt throughout its range. Conversely, NIS cover decreased with density (other study). This suggests that the plant is responding to factors at the higher elevation sites by producing more stems, and that the stems direct resources to seed production although the success of these seeds may be low. In a complimentary study of three Dalmatian toadflax populations we found that most of the stems were vegetative, and only a small percentage were from seed. Thus, our study suggests that Dalmatian toadflax is a well adapted species, and while it is not opportunity limited close to roads in our mountain system, its ability to establish and persist are related to climate and its capacity to reproduce vegetatively under less than ideal spatial or temporal conditions. Any changes in climate would likely result in range expansions due to little indication of ability based limitations.

Hybridization Between Yellow and Dalmatian Toadflax: Cause for Concern? Sarah M. Ward*[1], Marie F. Turner[1], Sharlene E. Sing[2]; [1]Colorado State University, Fort Collins, CO, [2]USDA-USFS, Bozeman, MT (114)

Hybrid toadflax populations resulting from cross-pollination between yellow and Dalmatian toadflax have been confirmed in Montana, Idaho, Washington and Colorado; these hybrid toadflax plants are viable fertile clonal perennials that could outcompete and displace the parent species. In common garden experiments conducted in Colorado and Montana, F1, BC1 and field-collected hybrids exhibited marked heterosis for several growth-related traits in addition to emerging from winter dormancy sooner and flowering earlier than the parent species. In greenhouse-based replacement-series experiments, pot-grown F1 hybrids outcompeted the parent species in biomass accumulation, providing further evidence that hybrid toadflax populations could pose a greater invasive threat than either Dalmatian or yellow toadflax. Because altered phenology in toadflax hybrids reduces herbicide efficacy, and biocontrol agents with strong host preferences may not establish on novel recombinant hybrid genotypes, hybridization between these two established invasive toadflax species presents additional management challenges.

New Developments in Biocontrol for Yellow and Dalmatian Toadflax. Sharlene E. Sing*; USDA-USFS, Bozeman, MT (115)

Yellow and Dalmatian toadflax infestations are strongly correlated with chronic (e.g., grazing, recreation, road-building) and catastrophic (e.g., wildfire, flooding) disturbances. Recent wildland surveys have, however, identified widespread, persistent invasions of both species in apparently intact and undisturbed locations. The highly selective nature of classical biological control can provide a feasible alternative to comparatively less selective chemical control, but only when treatments are predictably efficacious. Conservation of locally adapted native plant biotypes, avoidance of unintended nonpoint source pollution and worker safety/site accessibility issues indicate that biocontrol based treatments are well worth developing, particularly for use against toadflax invading fragile montane, steppe and rangeland ecosystems. Accurate host-agent matching and adjustments to agent release protocols proved to be key to optimizing biocontrol using approved agents such as the yellow toadflax (*Mecinus janthinus*) and Dalmatian toadflax (*M. janthiniformis*) stem mining weevils. Systematics, progress on host specificity testing and potential roles of candidate agents such as the stem galling weevils *Rhinusa pilosa* and *R. rara* sp. n., a ground-overwintering (as opposed to stem-overwintering) stem mining weevil *Mecinus laeviceps,* and the high elevation adapted *M. peterharrisi* will be discussed.

DISCUSSION SESSIONS

Project 1 Discussion Session: Weeds of Range and Natural Areas

Moderator: Jane Mangold, Montana State University, Bozeman, MT

Topic 1: *The Public Perception or Nostalgia in "Natural" Ecosystems (Public and Private Lands)*

A portion of the general public does not want herbicides used in "natural" environments. We need to recognize this and find ways to reach out to that audience. Some people really care about one organism/system and they wish to preserve or conserve that regardless of any other costs to the environment. In some cases, it is hard for them to look at a system comprehensively and understand how invasive plants might be impacting that which they care about most.

Moderator asked for examples from participants' geographical sphere of influence where public perception has played a role in an invasive plant management plan.

- Hanford nuclear facility; people want it restored to its natural state, but what is that state? We need to think about what we want the land to look like 50+ years from now, and we can't expect a degraded area to have all its original components even when restoration is complete.
- Staff turnover is high on many public lands. Management objectives and plans shift may shift when a new staff person (e.g. biologist) arrives on the scene, and it is sometimes difficult for him/her to understand how herbicide inputs in the past have been use to keep the rest of an area free of weeds.
- In spite of it seeming like the general public is against herbicides, the number of appeals/lawsuits associated with the NEPA process has declined. We are in one of the periods of lowest numbers of appeals and lawsuits since NEPA process came into existence, about 25 years ago.
- Some people have found that packaging the herbicide story to landowners as an *invasive species management issue* is much more effective. They have also found that explaining that new chemistries allow much smaller use rates with more precision/selectivity is effective.
- In some cases calling for action associated with a threatened species, such as sagegrouse, helps to get people supportive of invasive plant management and land management in general.
- In some circles, we've done a very good job of convincing people that herbicides are the way to go, but we need to do a better job of explaining to people what they can expect from a herbicide application.
- Media has helped out the herbicide industry, especially in the realm of wildfire. With the wildfire example, public can become more supportive of herbicide use to control weeds because some weeds contribute to wildfire.

Session continued with a discussion on the general public's perception of invasive plants.

- At least one study has been done that looked the non-market value of invasive plants. It was found that if a plant impacted a recreational activity, then people were behind the idea of spending money to manage that invasive plant.
- Big differences exist between agricultural and non-agricultural states in how the general public perceives invasive plants. Public awareness on a national scale has significantly dropped in the last few years. As far as the topic of herbicide use in natural areas, we need to remember that it's not just about herbicides, it's about invasive species in general.
- In the urban landscape, it is difficult to get people to get rid of invasive plants unless it is something poisonous/toxic that can cause harm to them. Some participants have found that this works better than talking about a noxious weed law that requires them to control invasive plants.

Moderator presented a couple recent papers on the topic of public perception of herbicide applications/invasive plant management in natural areas. These included

- Kelley et al. 2013. Managing downy brome (*Bromus tectorum*) in the Central Rockies: A land manager perspective. Invasive Plant Science and Management 6:521-535. This paper concludes that cost is a major constraint to downy brome management, control methods must be considered compatibile with existing operation, and there is still a need for basic education and outreach about downy brome identification, ecology, and management.
- Shindler et al. 2011. Public perceptions of sagebrush ecosystem management in the Great Basin. Rangeland Ecology and Management 64:335-343. This study broke results into urban and rural residents. Both urban and rural residents agreed that invasive plants were a major issue, but discrepancies between the two groups as far as accepting the use of herbicides to control them differed. Public acceptance of management is very high when it comes to prescribed fire, grazing, felling trees, mowing but not for herbicides and chaining.

Discussion continued on why some tools more acceptable than others.

- Some are perceived as being more natural, for example fire, grazing, biological control. Perception of "natural" tools may vary depending on the year, especially for something like fire.
- Some tools are more well-funded, such as fire.
- We need to remember that perceptions of risk vary considerably from person to person and place to place. Discrepancies between urban and rural residents in locations where general population is more closely tied to agriculture and natural resource might be smaller than if you go to regions of the country that are not as closely tied to agriculture/natural resources. It's very important to define your audience.
- In general, understanding of plants, ecology, natural systems, interactions with wildlife, etc. is not very high among urban residents.
- In urban settings, spraying and mowing are probably most widely used tools for invasive plants, and management is based on equipment knowledge, not science knowledge.

- An example was given from British Columbia where education has been very successful for using herbicides to control invasive plants. Signage is used with a QR code whenever a location is treated. People are taken to a website that explains why area is being treated and the general public is no longer concerned with the "how" because they understand the "why."

Moderator then led a discussion on identifying audiences that may be most in need of education.

- Ourselves, meaning we need to do it right the first time to avoid bad examples that get the public against herbicides in general. We need to get personal and look at ourselves before we start pointing fingers at other audiences or how they differ from us.
- Some entities have hired a full-time education coordinator who works to develop messages for specific audiences. Can we employ social marketing theory to move the general public beyond awareness of invasive plants to taking action to do something about them?
- Because the questions that you ask and the needs that people have changes with scale and geography, it may be worthwhile to approach education more strategically. There are many good examples of very successful and effective programs at the local scale, but the question of acceptability of herbicide use is a sub-set of the larger question of raising awareness and action about invasive plants. The benefits and drawbacks of a large-scale national campaign were discussed. Federally-involved land managers have talked to the National Ad Campaign about an invasive species campaign. $500,000 would be required to develop a national campaign.
  - Some national campaigns have been very successful (e.g. Smokey the Bear and "Only you can prevent forest fires.").
  - Others pointed out that it may be difficult to build trust at the local level around a national campaign. For example, would people in the semi-arid west be able to identify with an invasive species like kudzu?
  - Campaign would have to be targeted towards prevention and spread to be effective.
  - Campaign would need to focus on what you want your landscape to look like and how are you going to get there.
  - Everyone has relied on the federal government to take the lead and it hasn't happened; leadership has to come from the ground up from societies, local groups, citizens
  - Might be able to appeal to the general public by thinking about invasive species as "ecological pollution."
  - There are many more ways to reach local audiences/targeted audiences now than what we've had historically when national ad campaigns might have been more effective.
  - Scientists in general are not very good deliverers of the message. We need to turn education campaign over to professionals in marketing and advertising.

Moderator presented a list of some audiences that we may not normally reach and asked for other ideas. Those are listed below:

- Civic groups, e.g. Lions Club
- Recreational groups—non-sportsmen that utilize natural areas
- Master gardeners and garden clubs
- Audubon societies, native plant societies
- Sportsmen's groups
- Oil and natural gas/resource extraction entities
- Safety trainings with local industries
- Realtors
- Nurseries/horticultural groups
- Tribes
- Homeowners associations
- Small acreage owners

Moderator presented a few final slides that encouraged participants to think about what it might take to get the attention of those audiences and once we have their attention, what we might tell those audiences.

Moderator presented additional questions to ponder as we leave the session:

- How do we educate the public on the deleterious effects of not doing something vs. spraying a selective herbicide to locally control the invasive species?
- What strategies for managing invasive plants are we implementing now that we will look back in 20 years and wonder "what the heck were we thinking?"
- What is the next big issue that will be a big public perception hurdle?
- Is there a way to counteract the growing disconnect between rural and urban perceptions of invasive plant management?

Moderator closed with few comments and encouraged all participants to think about what he/she can do help to educate the general public both locally and nationally to help them become advocates for invasive species management in natural ecosystems.

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Project 2 Discussion Section: Weeds of Horticultural Crops

Moderator: Lynn M. Sosnoskie, University of California – Davis, Davis, CA

Topic: *Mechanization in Horticultural Crops: On the Ground and in the Sky; Can We Make the Machines Work for Us?*

Lynn began the discussion with a synopsis of where we are with weed control in specialty crops. From cotton gin, GPS guided tractors, drones, and now robotics, it is clear that technology has and could continue to play a role in development of weed management systems. How can we expedite the development of these new technologies? She referred to Steve Fennimore's blog of February 19, 2014 in which he encourages a new direction for weed science at UC Davis and beyond; a focus on the engineering of weed removal devices. Much of the ensuing discussion touched what is currently in use, recent innovations, and current roadblocks to development of mechanical or automated weed control devices (http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=12927). The specter of diminishing availability of labor coupled with shrinking herbicide utility, availability, and reduced efficacy (due to herbicide resistance) is a major concern of specialty crop producers.

Technologies currently being tested in Hort and specialty crops include weed seekers for post-harvest control in small grains, intra row cultivators that also double as crop thinners (RoboCrop), and optical thinners in lettuce. Major issues are still precision of operation as determined by deficits in image recognition algorithms, and the simple problem of speed. Specialty crops pose a special challenge because of the diversity of crops and management systems, and how to amortize very expensive equipment across many crops. Specialty crops can recoup costs quickly and provide some incentive for development.

Other points of interest included:

- Weed scientists often find themselves trying to make equipment work in old systems. Why don't we redesign systems to fit the capability of new machines?
- There is a lot of interest in equipment design for the 'big crops. How do we capture that interest for small acreage crops?
- Some producers need a continuous work force. What happens when new technologies create a labor void? Perhaps this will simply remove the back-breaking component of weed removal and give opportunities for individuals to take on more challenges roles. There may be pushback from labor unions if technologies threaten labor needs, as has happened in the past.
- We need to figure out how to pair biologists and engineers so that we can design better equipment. Weed scientists in WSWS have an herbicide bent, and most are not engineers. We have been mostly passive in the past, evaluating new technologies rather than creating them. Universities are particularly good at comparing new herbicide technologies. Registrants developed herbicides and we tested them. A new paradigm is needed where we pair with engineers. Should we be attempting to attract engineers to our society so that we can cultivate these relationships?
- How do we engage small startups, and attract the capital of larger foundations to begin this work? Can we work with the MacDonalds and the Walmarts of the world to achieve goals? Foundations may be more willing to take the long-view in development and tolerate a series

of baby steps that will eventually produce solutions. Some grower groups such as the Yuma Vegetable Growers are already beginning to fund development of mechanical weeders.

- What other groups could we work with? Perhaps emeritus engineers or High School robotic groups would be interested in working on these projects.
- University systems reward short term projects compatible with tenure goals. Publication number is very important and long term projects take a back seat. Granting cycles also reward projects with short term outcomes. Development of new technologies may take many years, and need small development steps that build on each other.
- The new FFRA program proposed in the recent US Ag budget may provide the opportunity to pair with industry. Do we need a committee to coordinate this work? Or a working group to bring interested parties together? Perhaps the formation of a WERA working group. Recently proposed Centers of Excellence may be a platform to organize from. Perhaps we could put out an RFA of our own to solicit cooperators.

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Project 3 Discussion Section: Weeds of Agronomic Crops

Moderator: Mayank Malik, Monsanto Company, Lincoln, NE; Prashant Jha, Montana State University, Huntley, MT

Topic: *Industry and Academia Perspectives on Managing Herbicide Resistance: Current Status and Future Strategies.*

This year's discussion was continuation from last two years discussion topic, where growers were aware of herbicide resistance issues either on their farm or neighbor's farm. They are also aware of the fact that herbicide resistance issues are spreading at an alarming rate and looking for ways to manage it. Therefore, it raised the question, what are industry and academia perspectives on managing herbicide resistance?

The discussion started off with the industry efforts on managing resistance. The approach included adding diversification to use of herbicides and promoting the use of residual herbicides, use of systems approach to manage weeds. The other methods included use multiple modes of action in the field and using weed management at different times of year. Industry is educating retailers, growers about crop rotation, rotate herbicide traits, and use of multiple modes of action. They are also providing technical information regarding herbicide-resistance management through technical bulletins to the sales people when they are talking to retailers. Some companies are also giving incentives to use residual herbicides in corn and soybeans. The hard part from this effort is to convince growers to use residual herbicides due to high costs involved in weed management.

The other part of discussion was the academic overview on herbicide resistance management. They emphasized the need of Integrated Weed Management strategies to manage herbicide resistant weeds. It included understanding biology and ecology of weed species in order to manage resistance. There was a discussion on how we can incorporate better agronomic practices along with herbicides to manage these resistant weeds. One of the practices was tillage that could be incorporated to manage some weeds, such as kochia. However, there are also some challenges associated with it especially in Northern Great Plains region where majority of the acreage is under dryland production. However, both industry and academics agreed that the weed management recommendations should match, so that there is consistency in our message being delivered to customers.

A greater part of this discussion was spent on how to train growers, retailers, dealers, and applicators about managing herbicide resistant weeds and understanding herbicide modes of action. There are a lot of young growers who have not seen many residual herbicides being used on their farms. Therefore, there is a need to train them about weed id, herbicide mode of action, and best practices to manage herbicide resistance. There was a discussion on how we can incorporate WSSA training modules for herbicide resistance management. One of the points was how we can give growers the long-term economic perspective on managing herbicide resistance. In addition, we also discussed how we can make certain changes in the label such as adding group numbers and adding weed efficacy tables on these labels. Some people emphasized the need of overall pest management training, including insect and disease management.

The other component of discussion was to make growers understand differences between various herbicide resistant traits coming up, so that they can use them effectively. It included making growers understand the importance of best management practices such as nozzle selection to manage off target movement, importance of sprayer clean-out to minimize tank contamination. The main purpose of this education is to make sure that growers get maximum long-term benefits out of these new technologies.

In conclusion, both academia and industry agreed that they should be on same platform with herbicide resistance management education. It included a combination of various forms such as you tube videos, webinars, handouts, extension and technical bulletins that will be helpful to educate growers. Then, there was also a discussion on creating an educational committee that can be part of herbicide-resistant plant committee. This committee should focus on regional aspects of herbicide resistance management and not overlap with WSSA educational committee. A suggestion was also made if there should be a symposium from WSWS at WSSA meeting to represent herbicide resistance issues from western region.

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Project 4 Discussion Section: Teaching and Technology Transfer

Moderator: Jeff Tichota, Monsanto Company, Centennial, CO.

Topic: *Potential New Dimensions in Your Weed Science Career*

The open forum discussion was lead by Jeff Tichota and Phil Westra, where the direction of a young career in weed science was discussed along with bridging the gap of weed science and other specialties and training venues. 17 members were able to sign in along with various other members of the society taking part in the discussion between other talks at WSWS in Colorado Springs, Colorado on March 11, 2014, 3:15pm to 5:00pm. After the open forum a short business meeting was conducted and Jenna Meeks of the University of Wyoming was selected as the Chair Elect for the Teaching and Technology section, Chair 2016.

The open forum had many presenters discussing their path in weed science, through gender considerations, cultural background and opportunities given as students. Common themes of keeping options open and that there are generally no biases associated with the society or the industry as a whole when considering gender or cultural background. Additionally, students in attendance were encouraged to take advantage of participation opportunities available within the society. Many questions arose from this recommendation, such as 'How does a graduate student feel confident about taking ownership in WSWS?' and 'How are graduate students to become more aware of these opportunities?' One popular solution to help graduate students in participation opportunities within the society, offer a shadowing opportunities with section chairs.

Industry and academic positions were discussed and how presenters chose their career. Presenters also discussed the importance of networking and the value of the society for offering such opportunities. Weed science is unique in the fact that it is the center of everything out in the field as problems, discussions, and solutions are usually done with many different disciplines in every day activities of a weed scientists.

Topic 2: Education of the General Public on Application of Herbicides

After the second session on March 12, 2014, a discussion was held. The main discussion was around the education of home owner type applicators and their affect on sensitive crops in the immediate area of their application.

Jim Gray of the 2, 4-D task force raised the question where in-depth discussion followed. The discussion first started with education at a point of sales for home owners and retailers on spray drift and sensitive crop injury concerns. It was also a point that many of the retailers and applicators of these products do not understand these concepts and generally don't follow label requirements of products. It was also asked why is spray paint behind locked doors and not pesticides?

As the discussion continued avenues for education were discussed and many in the room felt TV ads would not be the best method for dispersing educational material, as many people go to the web and social media for information. A suggestion of adding education material to the WSWS web page was suggested, so when people searched for information material would become available from many web searches.

In the end, it was agreed that we all hold a responsibility to start finding ways to educate these types of applicators before more regulation of herbicides in general would be recommended or enforced.

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Project 5 Discussion Session: Basic Biology and Ecology

Moderator: Brian Schutte, New Mexico State University, Las Cruces, NM.

Topic: *Identifying Potential Projects and Funding Sources for a Weed Biology Working Group in the Western US.*

Regional research projects on weed biology

Brian gave a short overview of the system to initiate multistate research. He noted that a portion of hatch act funds that are allocated for cooperative research among state agricultural experiment stations.

Regional oversight: the Western Association of Agricultural Experiment Station Directors.

State level oversight: State Agricultural Experiment Station Director.

There are different types of multistate research activities including research projects, coordinating committees and education/extension research activity. Rapid response research activity usually initiated by research directors based on need. Development committee usually involves creating new effort. There a multitude of different research and extension funds. Brian also shared a sampling of the current MRF extension/education and research activities. Finally he posed several questions to the group:

Are you interested in contributing to the development of a multi-state research project focused on weed biology, ecology and management?

J. Campbell asked if there was any project even close, and Brian indicated he was not aware of one.

There is a group in the North Central focused on integrated weed management. There is also a seed biology group.

A. Dille noted that the integrated weed management group was currently managing a common protocol that addressed climate change. Their intent is to write a NIFA grant.

Biology and ecology of weeds project would be of interest, as it would be potentially very broad. Not limiting it to a crop would be of interest. Seed biology, in particular, is particularly useful. There hasn't been a lot of recent work (although there is a resurgence very recently). Perhaps an emphasis on biology of emerging weed problems. Having a focus on emerging weeds could be based on potential range expansion. Using common protocols or even sharing germplasm and conducting common gardens could be a powerful approach to addressing emerging problems. *Kochia*, *Gallium*, *Vententata* were all mentioned.

Jointed goatgrass came up. Initiated in the early 1990's. Only really became a pressing issue when JGG expanded enough to affect many states.

A discussion about seed repositories occurred. There was considerable interest in such a system, particularly if it could be formalized into the USDA system for germplasm maintenance. Such a system could potentially quite complicated, but there may be a number of weeds already being stored. The system could be formalized under an umbrella of weeds.

Drew suggested a team that would be interdisciplinary, and would include diseases and insect pests. It was difficult for the group to identify a regional problem, and also what such a project would emphasize. What sort of structure would be needed to facilitate interaction? Perhaps the approach would be to work toward bringing diverse groups together, and then repeat the same discussion.

The group agreed that there could be a working group could be formed around a few of these ideas. Donn Thill seemed like an obvious choice for a director, as well as the director in NM.

The consensus was that there would be multiple groups needed to move some of these ideas into reality.

Brian and Joan both agreed to speak to their respective experiment station directors, and others indicated that they would also be willing.

Chair 2014:
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WESTERN SOCIETY OFWEED SCIENCE NET WORTH REPORT

April 1, 2013 through March 31, 2014

ASSETS	
Cash and Bank Accounts	
Checking	$61,771.56
Money Market	$84,818.52
TOTAL Cash and Bank Accounts	$146,590.08
Other Assets	
Asset (Weeds of the West unsold inventory)	$89,073.45
TOTAL Other Assets	$89,073.45
Investments	
RBC Dain Rauscher Acnt	$213,554.85
TOTAL Investments	$213,554.85
TOTAL ASSETS	$449,218.38
TOTAL LIABILITIES	$0
OVERALL TOTAL	$449,218.38

WSWS CASH FLOW REPORT

April 1, 2013 through March 31, 2014

INFLOWS	
Annual Meeting Income	$68,678.57
Bio Control Of Invasives Book	$243
California Weeds Books	$-176.15
DVD Weed ID	$162.61
Interest Inc	$207.14
Invasive Plants Book	$50
Renewal Membership	$1,860.00
Royalty For Proceedings Or RPR	$1,180.00
Student Travel Account	$1,083.00
Sustaining Member Dues	$12,200.00
Weed Control in Natural Areas	$1,481.43
Weeds Of The West	$18,306.42
TOTAL INFLOWS	$105,276.02
OUTFLOWS	
Annual Meeting Expense	$30,444.17
CAST Annual Dues	$1,500.00
Director Of Science Policy	$8,832.00
Herbicide Resistance Summitt II	$2,000.00
Insurance	$500.00
Merchant Account	$3,557.47
Misc	$-90.00
Service Contract	$23,000.00
Stipend	$1,500.00
Supplies	$91.43
Tax	$202.52
Tax Preparation	$691.65
Travel To Summer Meeting	$1,988.74
Travel To WSWS Meeting	$1,904.85
Web Stie Design	$7,500.00
Web Site Host	$620.00
Web Site Transactions	$2,500.00
TOTAL OUTFLOWS	$86,742.83
OVERALL TOTAL	18,533.19

WSWS 2014 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.

Dr. Robert "Bob" Norris

Dr. Robert Norris is an Emeritus Professor, UC-Davis. Bob was raised in the U.K. and graduated with a B.S. in Horticultural Botany from Reading in 1960. He did his graduate work at the University of Alberta in Crop Ecology and completed a Post Doctorate program in Horticulture at Michigan State University in 1967.

He joined U.C. Davis Botany department in 1967 and retired from the U.C. Davis Vegetable Crops Department in 2001. During his career at U.C. Davis, Bob taught Botany for non-majors, Weed Science, Weed Biology and Ecology, and undergraduate and graduate level IPM courses. Robert was one of the founding members of the U.C. IPM program and author of the only IPM textbook used for undergraduate teaching in the U.S. Through his research, he has developed and influenced weed management strategies in alfalfa and sugar beets and is considered a leading expert on soil seed banks. He is well known for his zero tolerance philosophy of letting weeds produce seed.

Bob is a Fellow of the WSSA and is an Honorary member of the California Weed Science Society. He has served as a reviewer for Weed Research, Journal of Applied Ecology, and Weed Technology (associate editor 13 years), and Weed Science (associate editor 4 years). He has also been active in the Master Gardeners program for over 30 yrs.

Bob has served the WSWS in many capacities; chaired the Research section, chaired the Chemical and Physiology section twice, and was the "Senior Ambassador" representing WSWS at the 2011 Weed Olympics in Knoxville, TN. Bob was editor of the WSWS Progress report in 1979. He has been active in WSWS for more than 40 years and made numerous presentations.

Dr. Robert "Bob" Stougaard

Dr. Stougaard is a Professor of Weed Science at Montana State University in Kalispell, MT. Bob received his B.S. in soil science from the University of Wisconsin in 1978 and initially worked as a sales representative for Shell Chemical in Illinois. Bob earned his M.S. in Weed Science from Southern Illinois University and Ph.D. in Weed Science from the University of Nebraska. He joined the University of Nebraska as an Extension Weed Specialist from 1987 to 1991.

Bob has been located at the Northwestern Ag Research Center in Kalispell for the past 23 years and is currently serving as the Superintendent of the station. His main areas of interest and expertise are integrated weed management in wheat, barley, canola and specialty crops. Of particular note were a series of highly referenced papers on the effects of wheat seed size, quality, and seeding rate on wheat and wild oat interference. Bob has expanded his research program to other disciplines, including entomology, plant pathology, and variety development, in order to serve the needs of the Montana clientele. Bob's research is relevant and addresses grower problems with a practical approach. As a result, he is highly respected by growers, crop consultants, and university research and extension colleagues. Bob has authored numerous extension publications, abstracts, and journal articles and has mentored graduate and undergraduate students.

Bob has been and continues to be a very active and important member of the WSWS. He has presented numerous times at WSWS and has served in leadership roles on the Board of Directors as Secretary, twice as Member-at-Large, and served as Agronomic Research Section Chair, Poster Committee Chair, and Placement Committee Chair. He has also served as an Associate Editor for Weed Technology, and served on the Awards committee and Resolutions committee of the WSSA.

WSWS 2014 Honorary Member

Dr. Dave Armstrong

Dave Armstrong has been the resident Naturalist at Sylvan Dale Guest Ranch in Loveland, CO since 1984. He received a B.S. from Colorado State University in 1966, M.A.T. degree from Harvard in 1967, and Ph.D. in Systematics and Ecology from the University of Kansas in 1971. Dr. Armstrong has had a very distinguished career and has numerous accomplishments. He has worked with Colorado State University, University of Northern Colorado, and the University of Colorado in Environmental studies, Natural Science, and Biology programs. He has served as associate curator of the University Museum, University of Colorado, the consulting curator at Denver Museum of Natural History, and as a senior scientist at the Rocky Mountain Biological Lab. Dr. Armstrong has taught numerous courses in natural science, ecology, mammalogy, and biology at the University of Colorado, supported and served on numerous graduate student committees, and has a lengthy publications list.

The WSWS particularly recognizes Dr. Armstrong's contributions to the Invasive Weeds Short Course as a special trainer. Dave has been a cornerstone of the Western Invasive Weed Short Course, not only by hosting the perfect venue at Sylvan Dale Ranch, but by providing insight into the practice of weed management. Dave has worked with the short course team to establish a long-term restoration plot where they have been able to demonstrate weed management combined with native grass establishment to participants. It has required considerable resources from the ranch in order to establish and maintain the plots. It was Dave's commitment to the goals of environmental education and improvement that made this possible. His knowledge about the flora, fauna and geology of Sylvan Dale Guest Ranch and the surrounding area has enhanced the experience for participants and trainers alike.

**WSWS 2014 OUTSTANDING WEED SCIENTIST, PRIVATE SECTOR –
Charlie Hicks**

Charlie Hicks is a Senior Tech Service Specialist with Bayer CropScience. I have observed Charlie’s involvement in Weed Science for nearly 20 years and have a shared history for about 15 years in our common employment for three companies. Charlie is extremely knowledgeable, considerate of other people around him, and the consummate weed science professional. He is a frequent presenter at WSWS annual meetings, and I have observed him successfully present three oral presentations in one meeting to cover his topics of expertise as well as filling in for another Bayer speaker who couldn’t make it. Charlie champions his territory with findings and results that are uniquely important and vital to his area. Supporters of Charlie use the words insightful or insights, and I have observed this as well when he has just the right picture that speaks 1,000 words on what he’s observing and sharing with others. His current handling of the “What’s New in Industry” session is an excellent example of his commitment to the WSWS and its members. Additionally, he is an avid mentor for graduate students and has served as chairman of several committees. It would be very gratifying and appropriate to have Charlie Hicks as the Outstanding Weed Scientist for the Private sector at the 2014 WSWS meeting being held in his home state of Colorado.

WSWS 2014 WEED MANAGER AWARD – Rita Beard

It has been my honor to work under Rita Beard's guidance over the last nine years as part of the National Park Service's (NPS) service-wide Exotic Plant Management Team (EPMT) program. In her role as the NPS's service-wide Invasive Species Coordinator, Rita not only oversaw the operation and implementation of 18 EPMT field programs, but was also responsible for guiding the entire NPS on the management and development of policy related to invasive plants. Rita was instrumental in organizing and expanding the NPS's invasive plant program, actively working to increase the number of NPS EPMT's, and the amount of funding available for weed management as well as communicating the importance of invasive plant management to NPS leadership. Rita's efforts in her role with the NPS have inspired several generations of weed managers, including myself. Rita is one of those rare managers for which no problem is too large or too small, whether it is taking just a few moments of her time to make a control recommendation to a manager in the field, or working to assist an entire network of parks with the development of a programmatic invasive plant management plan. Additionally, Rita has always supported the professional development of her field staff, encouraging them to attend and participate in professional meetings and societies (a number of us are now active members of WSWS), and by emphasizing the importance of utilizing current research and technology to make management decisions. In summary, I believe that Rita's tireless efforts to advance the cause of invasive plant management not only in the Western United States, but across the entire country, make her an excellent candidate to receive the honor of the Western Society of Weed Science's Weed Manager of the year in 2014.

WSWS 2014 PROFESSIONAL STAFF AWARD – Ed Davis

I first met Ed in 2004 when I was appointed as the MSU Cropland Weed Specialist. It did not take me much time to realize that Ed was not just a solid professional with extensive knowledge in weed management and high standard for research; he is an enjoyable and polite person ready to help. Ed research focuses on small grains, pulse crops, fallow, and forage crops and has extensive experience and understanding on rangeland and non-cropland weed management. Without hesitation, I would classify his knowledge of weed biology, ecology, and management as outstanding. He is extremely experienced on herbicides and their integration into sustainable weed management programs. As such, he is an invaluable member of our research and extension community and serves as a liaison between MSU Faculty and graduate students, framers across the state, and agrichemical industry reps. Ed was first appointed as the MSU Weed Science Research Associate in 1984. Since then, Ed has been appointed by three MSU Professors: Dr. Pete Fay, Dr. A.J. Bussan, and me. During these years, Ed collaborated with many other MSU Professors, Research Associates, and Technicians. Between 1991 and 1993, Ed was appointed as Assistant Professor in Weed Science at the MSU Central Agricultural Research Center. In his role, Ed evaluates new and existing technologies for weed control, crop sensitivity to herbicides, herbicide carryover/rotational crop response, screening and controlling herbicide resistant weeds, and crop desiccation/harvest aid. Among his many activities, Ed conducts field and greenhouse trials, oversees workers, assists undergraduate and graduate students, operates and maintains project equipment and machinery, compiles research results, and presents the results at professional and outreach meetings. Ed regularly presents the result of his research at professional societies as well as the Montana Agricultural Business Association, Montana Grain Growers Association, Montana Grain Elevator Association, and regional and local grower meetings. He has been invited to provide research updates and data exchanges by many agrichemical companies including Dow Agrosciences, Arysta LifeScience, Bayer CropScience, Monsanto, DuPont, BASF, Gowan, and Syngenta. Every year, Ed's dedication and effectiveness are reflected in the more than 45 field trials he conducts, the 35,000 miles he drives across Montana, and the competitive and non-competitive funding he secures to support this research. Ed is an active member of the Weed Science community including the Weed Science Society of America, the Western Society of Weed Science, and the Montana Weed Control Association. Between 1983 and 2012, Ed service in the WSWS spanned from Agronomic Crops Section Chair, to Session Moderator, and to Graduate Student Paper/Poster judge.

WSWS 2014 PRESIDENTIAL AWARD OF MERIT – Carl Libbey

President Roger Gast presented Carl Libbey with the Presidential Award of Merit for his long time service to the WSWS in many formal and informal roles, but especially for his faithful service as chief photographer and WSWS newsletter editor.

WSWS 2014 STUDENT SCHOLARSHIP RECIPIENTS

Our committee received five scholarship application packages. These young people are talented and our committee wished we had five scholarships to offer. Three individuals were selected.

Hally Berg – Montana State University (top)

Ashley Cunningham – New Mexico State University (bottom left)

Krista Ehlert – Montana State University (bottom right)

WSWS 2014 GRADUATE STUDENT PAPER AND POSTER AWARDS

Oral Paper Contest Awards – Range and Natural Areas & Horticultral Crops

First Place (middle) – Kallie C. Kessler, Colorado State University, Fort Collins

Second Place (left) – Thomas J. Getts, Colorado State University, Fort Collins

Third Place (right) – Jason W. Adams, North Dakota State University, Fargo

Oral Paper Contest Awards – Agronomic Crops & Basic Biology and Ecology

First Place (left) – Derek J. Sebastian, Colorado State University, Fort Collins

Second Place (middle) – Vipan Kumar, Montana State University, Huntley

Third Place (right) – Curtis M. Hildebrandt, Colorado State University, Fort Collins

Poster Presentation Awards – Range and Natural Areas & Horticultural Crops

First Place (left) – Julia M. Workman, University of Wyoming, Laramie

Second Place (right) – Jason W. Adams, North Dakota State University, Fargo

Poster Presentation Awards – Agronomic Crops, Teaching and Technology Transfer & Basic Biology and Ecology

First Place (right) – Vipan Kumar, Montana State University, Huntley

Second Place (middle) – Cody F. Creech, University of Nebraska, Lincoln

Third Place (left) – Nevin Lawrence, Washington State University, Pullman

Poster Presentation Awards – Undergraduate Poster

First Place – Hannah A. Tomlinson, University of Idaho, Moscow

WSWS 2014 ANNUAL MEETING NECROLOGY REPORT

Obituary for Clark Amen – 1919-2013

Clark was born on Aug. 17, 1919, in Walla Walla, Wash., to Catherine and John Amen. He grew up in the Walla Walla area. He was a navigator in the U.S. Army Air Corps during World War II. His plane was shot down in 1944, and he spent the rest of the war as a prisoner of war. He married Marjorie Cochran on Dec. 9, 1942. Following the war, they moved to Corvallis, where Clark graduated from Oregon State College with a degree in entomology. He worked for American Cyanamid Company for more than 30 years. Clark was preceded in death by his wife, Marjorie; his parents; and his brother, Frank Amen. He is survived by daughters Susan Hammond, Cathy Mattatall and Nancy Fischer; six grandchildren; and six great-grandchildren. A memorial service will take place at 2 p.m. Thursday, March 28, at Grace Lutheran Church in Corvallis. Memorial donations can be directed to American Legion Baseball in care of McHenry Funeral Home, 206 N.W. Fifth St., Corvallis, OR 97330. Please leave your thoughts and remembrances for the family at www.mchenryfuneral

Obituary for Mark Boyles – 1954-2013

Mark C. Boyles, 58, passed away in January 2013 in Tulsa, Oklahoma. Mark was born in 1954 in Guam, Mariana Islands. Mark graduated from Oklahoma State University with his Bachelor's degree in 1977, and again in 1979 with a Master's in Agronomy. After graduation, he began a career with Sandoz and BASF Agricultural Companies that spanned for 25 years as a research scientist until 2002. He had many patents and awards during this time, and in 2002 he created ProSearch One. In 2004, Mark went back to OSU as a faculty member and worked in Research and Extension for the Plant and Soil Science Department. While there, he co-developed and implemented the Okanola Project. He was a member of The Western, Northern and Southern Weed Science Societies where he served on several committees in 1992 through 1996 and is survived by his wife of 37 years, Maria, son Brandon and daughter Katie.

Obituary for Margaret "Ann" Henson – 1951-2013

Ann Henson of Longmont died June 13, 2013 at her residence. She was born on September 3, 1951 in Woodbury, New Jersey to Wilbur and Martha (Tate) Shea. In 1969 she left New Jersey and found her way to Colorado, where she met Tim Henson. The two later married on December 16, 1972 in Fort Collins, Colorado. Ann spent her career as a Research Scientist working for Dupont. She won the Crystal Award for her hard work and research for them. She also received an award from the Colorado Native Plant Society for her expertise with plant identification. She taught numerous classes on plant identification and numerous County agencies counted on her knowledge of native plants. As an avid Botanist she became a member of the Colorado Native Plants Society, and the Colorado Bryological Society. She liked hiking, traveling the world with her husband and painting. She will be missed by her family and all of the friends she made throughout the years. She is survived by her husband, Tim Henson of Longmont, brother John (Cindy) Shea of Washington and a sister, Paula (Raymond) Shea-Crispin of New Jersey. Her father also survives her. She was preceded in death by her mother. A celebration of Ann's life will be held at 11:00 am on August 24, 2013 at the Sandstone Ranch. Contributions in Ann's memory are requested to TRU Community Care Hospice, 2594 Trail Ridge Drive East, Lafayette, CO 80026.

Obituary for Lowell Jordan – 1930-2013

Lowell S. Jordan, Professor Emeritus of Horticultural Science in the Department of Botany and Plant Sciences, UC Riverside passed away on March 2, 2013. He was 82 years old. Dr. Jordan's research interests were in the areas of herbicide efficacy, herbicide physiology, and the mode of action of herbicides. Dr. Jordan was a Fellow of the Western Society of Weed Sciences, and of the Weed Science Society of America, and in 1982 received their Outstanding Teaching Award. Born on April 23, 1930, in Vale, Oregon, Lowell Stephen Jordan received his B.S. in Agriculture from Oregon State University in 1954 and his Ph.D. in Agronomy and Agricultural Biology from the University of Minnesota in 1957. He taught for a year at Southern Illinois University, and in 1959 became Assistant Plant Physiologist in the Department of Horticulture at UC Riverside as. In 1967 he received professorial rank in addition to the Cooperative Extension title. He retired in 1993. Dr. Jordan is survived by his wife, Catalina, 3 daughters, 2 sons.

Obituary for Dwight Van Peabody, Jr. – 1924-2013

Dwight Van Peabody, Jr. passed away peacefully after a long decline in health on August 3, 2013 in Shoreline with his family and caregivers at his side. Dwight (Bun) was born July 19, 1924 in Elyra, Ohio to Dwight Peabody, Sr. and Marion Mosher Peabody. He was raised in Canton, Ohio. He attended Western Reserve Academy in Cleveland where he graduated in 1943. After graduation, Dwight enlisted in the U. S. Navy Construction Battalion (Seabees) during WWII in the 11^{th}, 55^{th} and 77^{th} battalions. After the war, Dwight attended Ohio State University where he met and married Marjorie Kline and graduated with a BS in Agriculture in 1949. The moved to Pullman, WA where he graduated from WSU with a MS in Agronomy in 1951. After graduation Dwight was employed at the WSU Experiment Station at Mt. Vernon as an Agronomist/Weed Scientist 1951 until he retired in 1984. He contributed to the development of cash crops for Skagit Valley farmers and published many articles in his field based on his research work. Dwight and his second wife, Marintha Fortin Peabody retired to Lopez Island in 1985 where he resided at "Dunweedin" until 2008. Activities Dwight enjoyed included reading, anything related to Australia, wearing the oldest ragged clothes to make his family cringe, his cats, very dry vodka martinis straight up with a twist, being outdoors/farming and the Peabody Cousin Reunions. We will miss his quick dry sense of humor and his questionable tasteful limericks. Dwight and his former wife, Marjorie had four children: Eve (Seattle), Dwight Van III (deceased), Andrew (deceased), and Timothy (Duvall). He was preceded in death by his two sons, his wife, Marintha, step-daughter, Suzanne Fortin Gadbois and his special friend Alice Clow. Dwight is survived by his children, Eve and Tim, his two grandchildren (Kaitlynn and Joshua Dwight Peabody), his sister Margo (Dayton) Thome of Gardnerville, NV, three nieces in California and his 5 Gadbois step-grandchildren and great-grandchildren (Skagit County). He is also survived by his favorite cousin Dick (Berta) Parker, Albuquerque NM, his "faux" daughter Mary Clow (David) Wall in Mt. Vernon and his cat, Ben. His family would like to thank Gratiana, Michelle and Staff at Golden Hill Adult Family Home in Shoreline for the excellent loving care provided to Dwight. There will be a private family memorial at a later date in Seattle. In lieu of flowers, donations may be made in Dwight's memory to Homeward Pet Adoption Center, POB 2293, Woodinville, WA 98072 or to your local animal rescue shelter.

Obituary for Edward F. Sullivan Jr. - 1920-2013

Dr. Edward F. Sullivan Jr. August 7, 2013 Dr. Edward F. Sullivan Jr. of Clemmons passed away on August 7, 2013 at the age of 93. He was the son of the late Edward and Thelma Sullivan. He is survived by his devoted wife of 65 years, Madeline. Also surviving are his loving children, Edward Sullivan III and wife Joan McKenna; Hannah Sullivan; Anne Parra and husband Alvaro "Al" Gonzalez; Matthew Sullivan and wife Mary; three grandchildren, Madeline, Caroline, and Matthew; and one great grandchild, Quinn. Born 1920 in Scarborough, Maine, Dr. Sullivan grew up on his family's farm. He graduated from the CAA Civilian Pilot Training Program and served in the Army Air Corps as a ground-school instructor during World War II. He received a B.S. Degree in Agronomy from the University of Maine, and M.S. and Ph.D. Degrees in Agriculture and Forage Crops from Cornell University. Dr. Sullivan was a Professor of Agronomy at Southern Illinois University and Pennsylvania State University before becoming Manager of Crop Protection at the Great Western Sugar Company in Longmont, Colorado. After retiring in 1984, he and his wife relocated to North Carolina to be closer to family. Considered one of the world's foremost authorities on crop protection and soil erosion, Dr. Sullivan authored numerous scientific articles and contributed to several agricultural patents. He was elected to the International Institution for Sugar Beet Research in Brussels, Belgium; and received the Meritorious Service Award from the American Society of Sugar Beet Technologists. His professional memberships included the American Society of Agronomy, Weed Science Society of America, and the International Institute for Sugar Beet Research. He was also a founding member of the Plant Growth Regulator Society of America. A private memorial mass, officiated by Rev. Brian Cook, was held at Holy Family Catholic Church in Clemmons on August 24, 2013. The family wishes to extend its gratitude to Novant Health West Forsyth and the Kate B. Reynolds Hospice Home for their care and support. In lieu of flowers, donations may be made to the KBR Hospice Home, 101 Hospice Lane, Winston-Salem, NC 27103.

WSWS ANNUAL MEETING ATTENDEES – Colorado Springs 2014

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WSWS 2014 ANNUAL MEETING – AUTHOR INDEX

This is an index of authors and their abstract numbers.

WSWS 2014 ANNUAL MEETING – KEYWORD INDEX

This is an index of keywords and the numbers of the abstracts where they appear.

WSWS 2014 ANNUAL MEETING – ABSTRACT NUMBER, PAGE NUMBER INDEX

2013-2014 WSWS Standing and Ad Hoc Committees *(board contact)*

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Carol Mallory-Smith (2016)

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(Member-At Large-Private Sector)
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Fara Brummer (2016)

<u>Herbicide Resistant Plants</u>
(Member-At-Large-Private Sector)
Andrew Kniss, Chair (2015)
Sarah Ward (2014)
Brian Jenks (2016)

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Joel Felix (2014)

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