PROCEEDINGS

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These proceedings are dedicated to the
"Resiliency of Our WSWS Membership"

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2021

PROCEEDINGS

OF

THE WESTERN SOCIETY OF WEED SCIENCE

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PAPERS PRESENTED AT THE ANNUAL MEETING

MARCH 1-4, 2021

PREFACE

The Proceedings contain the written abstracts of the papers and posters presented at the 2021 Western Society of Weed Science and Western Aquatic Plant Management Society joint annual meeting plus summaries of the research discussion sections for each WSWS Project. The number located in parenthesis at the end of each abstract title corresponds to the paper/poster number in the WSWS/WAPMS Meeting Program. Authors are indexed separately. Index entries are published as received from the authors with minor format editing.

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

Proceedings Editor: Carl Libbey

GENERAL SESSION

WSWS/WAPMS 2021 Virtual Meeting Welcome. Sandra K. McDonald*; Mountain West Pesticide Education and Safety Training, Fort Collins, CO (052)

Welcome to the 74th annual meeting of the Western Society of Weed Science and the 1st virtual meeting. We are also excited to have the Western Aquatic Plant Management Society joining us. The WSWS/WAPMS Planning Committee has work diligently to create a virtual meeting that succeeds in retaining what makes our meetings special.

First is the science, we feel that quality science can be presented in a virtual platform as easily as the in-person format. This year in addition to the WSWS Project sessions and the WAPMS session, there will be three symposiums. The Biocontrol Symposium will include both terrestrial and aquatic weed biocontrol.

Second is our commitment to our students. The Student Presentation Committee has worked hard to make the poster and paper sessions as rewarding for the students as possible.

Third are the WSWS Project Discussion Sessions. The Planning Committee built on these discussion sessions to include a series of Live Roundtable Discussion sessions moderated by our members.

The Planning Committee has done its best to provide an engaging virtual meeting experience. The success of the meeting depends on the participation of the attendees, so please participate.

Thanks to the WSWS Board of Directors and all the Committees for their extra efforts and support of the Planning Committee. Finally, thanks to the entire Planning Committee:

Mithila Jugulam, WSWS Research Section Chair
Todd Neel, WSWS Education & Regulatory Section Chair
Mirella Ortiz, WSWS Graduate Student Association President
Tom Warmuth, WAPMS President
Cory Greer, WAPMS Vice-President

WSWS Presidential Address. Corey V. Ransom*; Utah State University, Logan, UT (053)

It is a pleasure to welcome you to the 74th annual and 1st virtual meeting of the Western Society of Weed Science. I'm pleased that we are meeting jointly with the Western Aquatic Plant Management Society. I would like to announce the new officers for our society: Joel Felix as President-elect, Harlene Hatterman-Valenti as Research Chair-elect, Jane Mangold as Education and Regulatory Chair-elect, and Phil Banks as treasurer. We appreciate all of those who were willing to run for office and for the service that individuals give to our Society. I would also like to congratulate those who will receive awards and recognition of their accomplishments during our meeting. I also want to express appreciation to the chairs and committee members of the various committees for all that they do and for helping our society to move forward. I express special appreciation to the program committee, chaired by Sandra McDonald, for all of the work that they have done to make this meeting a possibility in a new platform and in a new way. I also appreciate Eric Gustafson for the work he does in supporting our society. I would also like to give a special recognition to our ad-hoc Diversity and Inclusion Committee that was chaired by Elizabeth Mosqueda for their work in drafting a diversity and inclusion statement for the society that we will have an opportunity to vote on in our business meeting on Thursday morning. I appreciate their thoughtfulness in putting this together for us.

Today I will talk about drawing upon the past as we build our future. Wow, 2020! What a year! A few years ago, when I was approached about running for president, I looked at the schedule and figured if I was elected that I would be president in the year that we would meet in Boise, Idaho. Something felt comfortable to me about that because I had lived near Boise for about eight and a half years when I worked for Oregon State University and I thought that meeting there will feel close to home. Little did I know I would actually be speaking to you from home and I'm not sure that this is any more comfortable! I would really love to be visiting with you face-to-face. The year 2020 has provided numerous challenges, but for me it's been a time to evaluate priorities, a time to try some new things, even things I'm not very good at. It has provided some time to adapt to the new realities of life and to figure out how to continue to be effective in my job and in my different roles under these conditions. I think it has been a great time to gain perspective and to put things into perspective.

For me, one of the positive things of 2020 is that it caused me to live more in the present. When I face challenges, I like to look back into my personal history to find context and perspective from those who came before me. There are three individuals that I respect a lot. Peter Kirby and George Ransom are my two grandfathers, and both worked hard to make a living during the Depression, Peter as a sharecropper and George as a homesteader, mechanic, blacksmith and whatever he could do to earn a living. I really like a picture I have of George in a baseball uniform because it shows that even in the hard times people gathered together to find joy amongst the difficulties. I also appreciate that in the picture you can see how hard he worked by the light color of his arms in contrast to his dirty and weathered hands. I deeply respect my father, Wendell Ransom. He celebrated his 21st birthday on the battlefield in World War II in France. Just a few days after his birthday there he was injured by a mortar round and returned home from the battle. Previous generations have faced difficult circumstances and not only survived but prevailed.

As I look back at the history of WSWS, the second meeting of our society in 1939 was held in Berkeley California. Harry L. Pence said, concerning a bill being forwarded by a senator,

". . . The bill in my judgment is a distinct step toward obtaining Federal recognition and financial aid for weed control. In my opinion there is still gross misunderstanding relative to the problems of noxious weeds in most sections of the United States." I think if you read the current legislative report by Lee Van Wychen you will find that some of these same challenges still exist with our field of science today. In a meeting held in Bozeman in 1949, Arnold Appleby highlighted some of the things that were discussed. He said that in the proceedings it mentioned that "further research on the Electrovator was being discontinued in several States because of high cost and poor performance." Also, at this meeting the society's name was changed from the Western Weed Control Conference to the Western Weed Conference. I am not sure that would be a good name today considering the added focus on the term "Weed" in connection with marijuana. A new business that has arrived in Ontario, Oregon since I lived there is called “Weedology” and has nothing to do with weed management. Even back in 1949 there was some discussion about what name the society should use. At this meeting, a member of the society proposed that the term “herbology” be used as the name for weed science. In 1975 at the annual meeting in Phoenix Arizona, the Public Relations Committee submitted the following recommendation, which I think shows the frustration they felt in trying to communicate with the public about the use of pesticides. They wrote, “It is critical that we get information into non-agricultural oriented news media,” and they suggested a men's and a lady's Journal could be an avenue for this communication. They stated that “another could be the Ladies Home Journal” with article titles like “Good Family Health Through Proper Herbicide Use” or “Are They Trying to Starve Your Family Through Banning of Pesticides?” The committee chair reported, “I regret I have not noticed such articles in the popular press.” Once again, we continue to struggle today with how to communicate with the public on these important issues. In 1982, the annual meeting was held in Denver, Colorado and a proposal was made from the Western Aquatic Plant Management Society that they affiliated with the Western Society of Weed Science. I think it's so appropriate that we're meeting jointly this week. Alex Ogg, who was the president at this meeting, raised the possibility of initiating a graduate student paper contest. What a great idea considering how important that contest is to our society today. Two symposia were offered: “Weed Control Applied Research and Who Will Do It in the Future,” lead by Gary Lee, and “How to Train Graduate Students for a Future Career in Weed Science,” led by Arnold Appleby, who was a master in training weed scientists throughout his career.

My first meeting with the Western Society of Weed Science was in 1992 in Salt Lake City. During that meeting, Kansas, Nebraska, and North Dakota joined the society, even though members had attended from those States for years. Two years previously the society established sustaining memberships and 15 companies supported the society in 1992. Additionally, the Western Society of Weed Science joined with the National and other Regional Weed Science Societies in providing support for the Congressional Science Fellow, recognizing the importance of our representation in the legislative process. During the general session, Gary Lee talked about “Progress, Perceptions, and Challenges of Weed Science.” Paraphrasing his talk, he said that about 25% of weed scientists felt like they were paid more than average and 65% felt they were paid similarly to their colleagues in other fields. He also said that 65% of weed scientists felt that they work harder than their colleagues and in general felt and that they were more productive. Maybe that is what appealed to me about weed science, receiving the same pay for harder work? Bruce Ames then gave a general session talk titled, “Human Cancer: Are Pesticides Responsible?” Parts of this talk have stayed with me throughout the years. He said:

> “In the last several decades there has been a persistent widespread belief among many groups in this country that nature is benign and that man-made things, i.e., modern technology, have destroyed our benevolent relationship with nature. This yearning for a time when man was happily in harmony with nature is a yearning for a time that never existed: In reality, life before the modern industrial era was for most people, even in Thomas Hobbes’ time, ‘nasty, brutish, and short.’ Disease and malnutrition ensured a very short life expectancy, an early end to the misery of life in the natural world.”

And then later on in his address he said, “Synthetic pesticides have markedly lowered the cost of vegetables and fruit, thus increasing consumption. Other than giving up smoking (causing 30% of cancer and 25% of heart disease) eating more fruits and vegetables and less fat may be the best way to lower risks of cancer and heart disease.” Again, I was impressed with these presentations. Alex Ogg, who was the president, said, “Don't forget the old methods of weed control including crop rotation and cultural methods and livestock management.”

I think it is interesting since the beginning of the society that integrated approaches to weed control have been discussed and reinforced. This was Arnold Appleby’s summary of my first meeting: “Of the presentations, there were as usual, many having to do with chemical control including a number on the important topic of herbicide-resistance. However, there were discussions on the use of lasers for weed control, selective control by harrowing, weed control by soil bacteria, computer programs for weed management systems, DNA sequencing, studies on weed seeds, etc.” It is fun to see the progression of the topics throughout the years. After the 1992 meeting, I came home and told my wife that I was definitely pursuing the right field of study.

For me, the Western Society of Weed Science has provided a professional home. It provides recognition and remembrance of both the accomplishments and the lives of its members. It provides opportunities for skill development. I learned photography techniques from a true professional photographer, Robert Norris, a member of our society. The society provides an opportunity to receive feedback from peers and to interact with them. It provides sources of inspiration, new ideas, and creativity. The society provides opportunities for collaborations. Through the Western Society of Weed Science I have developed many dear friendships; friendships that extend beyond the work environment. Our society provides opportunities for student development. It has been fun to watch students as they have progressed from student to professional in their careers. Through our legislative representation, WSWS represents my interests at the regional and national level.

Not everything from the past is relevant. When I began my career at an experiment station with Oregon State University, Arnold Appleby sent me some suggestions for success. He titled the packet, “Suggestions and Philosophy of an Old Fogey.” Many of the things included were great advice and I've tried to work on them throughout the years. He suggested to write your papers before you begin the research then you'll know the type of data you need to collect. Keep your resume up to date. Be a dependable cooperator and give credit when credit is due. Surround yourself with the best assistants. Recognize other’s accomplishments. I especially like this one -- let others find out how good you are without you telling them. And finally, the one that has made me chuckle throughout the years, learn to dictate. He claimed he could come in at 7 a.m. and have ten letters dictated by 8 a.m. At that time in my career, if I had learned to dictate it would have been of no benefit, since I still would be the person who would have to type the letter. Obviously, there are a few things that changed between Arnold Appleby's time in his career and the time that I began my career.

A lot has changed since the Western Society of Weed Science began. I glad that modern herbicides have lower use rates. I found some papers from the 1940’s documenting trials with treatments providing effective vegetation control with Borax at 8 lbs/A. The weeds have changed through time as have the management tools and chemicals available. Our capacity has increased with the development of computers and other modern technologies. Regulations have changed, many for the better, increasing safety to the environment and to human health. I am unsure if public perceptions have improved or not. It often seems that we still face some of the same battles from the very beginning of our Society. I think many of our own perspectives have changed. I also believe our perspectives can be enhanced by looking to the past and realizing how they were able to successfully face the challenges of their time. With all of this change, I would propose that the core values and mission of our society remain the same. The Western society Weed Science has grown through time. Due to foresight of the authors of the Weeds of the West, our society has had great financial stability throughout the years. We have seen fluctuations in membership. The focus and depth of the research that our members are conducting has changed. Our society continues to change; more recently, in 2010 we established a student liaison position to the board so that our students would have a voice in our society. In 2014 we adopted an ethics statement for the society. Even in 2019, our president that year, Andrew Kniss, brought our beautiful logo into the 21st century by having it redone in a high-resolution. This year, in 2021, we have the opportunity to adopt the diversity inclusion statement that has been generated by the Diversity and Inclusion Committee. We are grateful for that work. All the changes that happen in our society are due to the interest and vision of its individual members. So here we are in 2021. I realized that a meeting in a virtual space is not very comparable to a meeting held in person in a place like Hawaii or Boise, but I think that we can adapt to change. When I came to Utah State University my office was in the building where I completed my master's degree and I was actually assigned the office where my Major Professor, Jack Evans, had been housed. Several years later, the old building was demolished, and we moved into a brand-new building with all of the modern design and technology. It is also very beautiful to look at. However, what I found is that when our department moved from the old building to the new building very little changed within our department. That is because it's really all about the people. I think the Western Society of Weed Science is all about the people.

So, what can you do during this meeting and going forward to help build the society? Be engaged in the meeting. Look for opportunities to serve our society. Attend the presentations and participate in the discussion groups that have been carefully provided for this meeting. Involve your students in the meetings and let them know how much WSWS means to you. Involve others and invite colleagues from other disciplines that might not have previously attended. Respect each other's opinions. Be nice even when you are offering constructive criticism. Reach out to people that you don't know. Let's continue to build on the solid foundation provided by those in the past so that our society can succeed as we move toward the future. I hope that you enjoy the meeting and wish you all the best. Thank you!

WAPMS Presidential Address. Tom Warmth*; BioSafe Systems, Kure Beach, NC (054)

The introduction welcomed the participants of the meeting and thanked them for their involvement with the new format of the virtual conference. The WAPMS society was happy to finally be having their meeting one year prior to it being cancelled in 2020, tentatively rescheduled for October, that date also being cancelled, and the program being moved to the joint meeting with WSWS. The WAPMS' last meeting was the APMS/WAPMS joint meeting in San Diego in July 2019, so it had been almost 2 years since the last WAPMS meeting. Thanks were given to all of the contributors to the content of the oral and presentations, without their efforts to create the content and then record their presentation we wouldn't have had a meeting at all. The importance of having these forums to share information and fostering discussion in our areas or expertise was brought up and that in one format or another (virtual or in person) it is critical that there are efforts made to continue to make them available to disseminate information and to give new and relevant research a platform. This joint meeting for WAPMS was about contributing content and our perspective to the more terrestrial focused WSWS. It is one focus for WAPMS moving forward that as the needs change for professional meetings like WASPMS and WSWS, that the WAPMS would be one source for information on "aquatic" content, speakers or general references in that surface water realm. The availability of applicator license recertification credits for the majority of the western states was also something provided by WAPMS for those holding aquatic herbicide licenses and attending the WAPMS sessions (a big thank you to Carolyn Ruttan for all of her efforts coordinating with the individual western states for the CEU's!!). The next meeting for WAPMS will be held in Tucson in March 2022 at the same location it was planned to be in 2020.

Western Wildfires: USDA Forest Service-Fire Year 2020 and the Path Forward. Patricia Grantham*; United States Forest Service, Acting Director of Fire and Aviation Management, Washington, DC (055)

The 2020 fire year was remarkable, horrifying, and record-setting. 4.8 million acres of National Forest burned in 2020 just shy of the 5 million acres burned in 1910, the year of the "Big Blowup" in Idaho and Montana. 2020 also set a record for the number of firefighters and support personnel deployed, almost 33,000 across the Nation. In 2021, we anticipate another extreme fire year, beginning as early as June in the Southwest. There have been 21 years where over 1 million acres of National Forest Land have burned; 14 of those years have occurred since the year 2000. This is a problem of epic proportions - what have we done over the years to address wildland fire and slow this trajectory of severe wildfire? In 2000, the National Fire Plan identified four goals: 1) Improve Fire Prevention and Suppression; 2) Reduce Hazardous Fuels; 3) Restore Fire Adapted Ecosystems; 4) Promote Community Assistance. Between 2010 – 2013, a cohesive strategy was developed to focus on three pillars: 1) Creating Resilient Landscapes; 2) Promoting Fire-Adapted Communities; and 3) Safe, Effective, Risk-Based Response. Using the concept of "firesheds" and changing fire-return intervals, a multi-agency, all-lands approach has been taken to identify priority project areas that include private lands to implement the cohesive strategy. The only solutions is one that is scaled to the accelerating scope and scale of the problem, and is co-developed and owned by partners across all land ownerships.

POSTER SESSION

Aquatics

Evaluating Potential Algaecides for Algae Management in California Rice. Sara Ohadi*[1], John D. Madsen[2], Kassim Al-Khatib[1]; [1]University of California, Davis, CA, [2]USDA-ARS, Davis, CA (050)

Nuisance algae have always been a challenge for rice production in California. Our previous study showed that unmanaged algae infestation at the beginning of the season can dramatically reduce rice seedling emergence and establishment. Copper sulfate in the form of "Blue Stone" is recommended to the water when an algal bloom is observed. Proper algaecide application is suggested to increase the algae-free window and successful rice establishment. A field experiment was conducted during Summer 2020 to 1) evaluate various algaecides and their time of application on controlling algae bloom in rice and 2) understand under which algaecide treatment rice has the best establishment. Seven algaecide compounds including Algimycin, Cutrine-Plus, Cutrine-Ultra, Copper sulfate (in both dry and liquid form), Hydrogen peroxide, and Hydrothol-191 were applied into the infested plots (10x10 feet) at planting day and seven days after planting. All the algaecides were applied at one dose (i.e. recommended dose by the label). The algae converge was scored (0-100) at 2, 7, and 14 days after algaecide application. Permanent quadrats (bottom-cut five-gallon buckets) were randomly placed inside each plot to estimate the seedling establishment. Sixty pre-soaked M-206 were spread inside the buckets. The number of established seedlings were counted over the period of the experiment. The results show that maximum algae reduction occurred 2 days after treatment for both application timing, but the 7 days after planting had greater algae reduction. Hydrogen peroxide (80%), Hydrothal (68%), and liquid copper sulfate (65%) showed the highest algae reduction when they were applied at rice day of seeding, whereas liquid copper sulfate, Hydrothol-191, and Cutrine-Plus controlled algae more than 80% when they applied seven days after planting. Although no visuall injury observed on rice seedlings, the number of established seedling were affected by the algaecides and their time of application. Overall, the percentage of rice seedling emergence was higher when algaecides applied at the planting date than the application of algaecides a week after planting. The maximum rice establishment was observed at liquid copper sulfate, Cutrine-Ultra on the day of planting application. Furthermore, the percent of rice establishment at Hydrothoal-191 and Algimycin were similar to the untreated control (application at planting time). Our results suggested that algaecides were more effective in controlling algae at seven days after planting.

Simulated Mechanical Control of Flowering Rush (*Butomus umbellatus*) Under Mesocosm Conditions. Gray Turnage*[1], John D. Madsen[2], Ryan M. Wersal[3], John D. Byrd[1]; [1]Mississippi State University, Starkville, MS, [2]USDA-ARS, Davis, CA, [3]Minnesota State University, Mankato, MN (051)

Flowering rush (*Butomus umbellatus* L.) is an invasive aquatic and wetland plant capable of developing monotypic stands in emergent and submersed sites. This plant can rapidly outcompete native vegetation and impede human practices by reducing recreation (boating, fishing, and skiing) and disrupting agriculture use (irrigation canals). Mechanical removal practices occurring biweekly, monthly, bimonthly, and once per growing season, was compared to chemical control with diquat applied sequentially at 0.19 ppmv ai two consecutive months over two years (2016 and 2017). Biweekly removal gave the most consistent control of flowering rush biomass and propagules. Diquat application along with monthly and bimonthly clippings gave varying degrees of flowering rush control. Clipping once per growing season did not control flowering rush when compared to reference plants while clipping flowering rush every two weeks (biweekly) controlled rush propagules most effectively. However, it is unlikely this method will be sufficient as a stand-alone control option due to the slow speed of harvester boats, potential these boats have to spread flowering rush propagules to more sites, and the expense of mechanical operations. However, clipping could be used as part of an integrated strategy for flowering rush control.

Education and Regulatory

2020 Survey Results for the Most Common and Troublesome Weeds in Grass Crops, Pasture and Turf. Lee Van Wychen*[1], Lavesta C. Hand[2]; [1]Weed Science Society of America, Alexandria, VA, [2]University of Georgia, Tifton, GA (049)

The 2020 Weed Survey conducted by the Weed Science Society of America surveyed weed science members for the most common and troublesome weeds in the following grass crops: 1) corn (*Zea mays*); 2) rice (*Oryza sativa*); 3) sorghum (*Sorghum bicolor*); 4) turf; 5) pastures, rangeland, or other hay; 6) spring cereal grains; and 7) winter cereal grains. Common weeds refer to the weeds you most frequently see while troublesome weeds are the most difficult to control, but might not be widespread. There were 317 total survey responses from the U.S. and Canada, of which 115 were from the following 19 Western Society of Weed Science (SWSS) states and provinces: Alaska, Alberta, Arizona, Colorado, Hawaii, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, Saskatchewan, South Dakota, Texas, Washington, and Wyoming. There were no survey responses from British Columbia, California, or Utah. The following weed survey results are specific for the WSWS states and provinces. In corn, the top three most common weeds were 1) *Setaria spp*.; 2) kochia (*Bassia scoparia*); and 3) Palmer amaranth (*Amaranthus palmeri*); and the most troublesome weeds were 1) kochia; and 2) a tie between Palmer amaranth and waterhemp (*Amaranthus tuberculatus*). In sorghum, the top three most common and most troublesome weeds were 1) kochia; 2) Palmer amaranth; and 3) johnsongrass (*Sorghum halepense*). In turf, the top three most common weeds were 1) *Digitaria spp*.; 2) annual bluegrass (*Poa annua*); and 3) dandelion (*Taraxacum officinale*); and the most troublesome weeds were a three-way tie among annual bluegrass; *Digitaria spp*. And *Cyperus spp*. In pastures, rangeland, and other hay, the top three most common and most troublesome weeds were 1) *Bromus spp*.; 2) Canada thistle (*Cirsium arvense*); and 3) musk thistle (*Carduus nutans*). In spring cereal grains, the top three most common weeds were 1) *Brassicaceae spp*.; and 2) a tie between common lambsquarters (*Chenopodium album*) and wild oat (*Avena fatua*); and the most troublesome weeds were 1) kochia; 2) wild oat; and 3) *Setaria spp*. In winter cereal grains, the top three most common weeds were 1) *Bromus spp*.; 2) *Brassicaceae spp.*; and 3) kochia; and the most troublesome weeds were: 1) *Bromus spp*.; 2) field bindweed (*Convolvulus arvensis*); and 3) a tie among

Italian ryegrass (*Lolium perenne L. ssp. multiflorum*), jointed goatgrass (*Aegilops cylindrica*), and cereal rye (*Secale cereale*). Among all grass crops in the WSWS states and provinces, the top three most common weeds were 1) *Bromus spp*.; 2) kochia; and 3) *Brassicaceae spp*.; and the most troublesome weeds were: 1) *Bromus spp*.; 2) kochia; and 3) a tie between Canada thistle and johnsongrass. The 2020 weed survey data is available at: www.wssa.net/wssa/weed/surveys/.

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

Effects of Indaziflam Treatment on Seed Bank Density and Richness in a Sagebrush-grassland Plant Community in Sublette County, WY US. Jacob Courkamp*[1], Paul Meiman[2]; [1]Colorado State University, Fort Collins, CO, [2]University of Nevada-Reno, Reno, NV (016)

Mitigation of annual grass invasion is critical to halting the conversion of native rangelands to fire-prone, annual grass-dominated communities. The herbicide indaziflam is a promising new tool that may allow managers to selectively deplete annual grass seed banks in plant communities that continue to support desirable perennial vegetation. The potential for non-target impacts to the seedlings of other species in the seed bank is not well-understood. To assess the potential for non-target impacts, we collected seed bank samples from three treatment (73g ai/ha) and control plots in an invaded sagebrush-grassland plant community near Pinedale, Wyoming. Plots were treated with a helicopter in September 2016 and samples were collected in October 2019, three years after treatment. Because indaziflam is more likely to have effects on seedlings that germinate near the soil surface, samples were divided into shallow (0 to 1cm) and deep (1 to 5cm) seed banks. Germinating seedlings from these samples were tracked over a period of 20 weeks in a greenhouse with regular watering, and these data were used to compare the density and richness of the seed bank between treatment and control plots. Preliminary results suggest that: (1) the perennial seed bank is very sparse at the research site; (2) the majority of seeds occur in the shallow seed bank; and (3) indaziflam treatment appears to have reduced the richness and density of the native species seed bank, with most of the impacts occurring to native annuals.

Cheatgrass Seed Bank Densities Following Imazapic and Indaziflam Treatments. Charlie D. Clements*; USDA-ARS, Reno, NV (017)

The accidental introduction invasion of cheatgrass throughout millions of hectares of Intermountain West rangelands has resulted in the conversion of formerly big sagebrush/bunchgrass communities to annual grass dominance. Resource managers need tools to conduct aggressive and effective weed control practices on cheatgrass-infested rangelands to improve restoration/rehabilitation efforts. The use of pre-emergent soil-active herbicides can be very effective in decreasing cheatgrass seed bank densities and above-ground densities that limit the establishment of perennial species. Pre-emergent soil-active herbicides, *Imazapic* and *Indaziflam* were applied in the fall of 2018 our Bedell study site in northern Nevada to test efficacy on cheatgrass control. We apply these pre-emergent herbicides in the fall of the year prior to any fall germination of cheatgrass and fallow the site for 1-year prior to seeding desirable species. Due to the continued residue of these soil-active herbicides, cheatgrass seed bank densities were measured post-seed set the second year following application. Seed bank densities in *Imazapic* treated plots ranged from 484 - 3,486 cheatgrass/m² averaging 1,722 cheatgrass/m². Cheatgrass seed bank densities in the *Indaziflam* treated plots ranged from 0 - 463 cheatgrass/m² averaging 58 cheatgrass/m². Untreated plots ranged from 1,356 - 4,164 cheatgrass/m² averaging 2,496 cheatgrass/m². It is reported that *Indaziflam* has the potential to control cheatgrass germination up to 4-years, therefor, there may be a residual effect of this herbicide that continues in the soil to effectively decrease cheatgrass seed bank densities past the initial 1-year fallow-seeding method, if so this residual effect may also limit seedlings of seeded species.

Integrating Seeding with Indaziflam: Evaluating Establishment of Grasses, Forbs, and Shrubs. Jodie A. Crose*[1], Brian Mealor[2]; [1]University of Wyoming, Sheridan, WY, [2]University of Wyoming, Laramie, WY (018)

Indaziflam is a preemergent herbicide recently labeled for use in rangeland systems. It effectively controls annual grasses with an extended soil residual with minimal impacts to established perennial species richness and abundance. Competition from annual grasses can affect the success of newly-seeded species. Indaziflam may be a tool to reduce competition for seeded desirable species. We evaluated emergence and establishment of 48 native grass, shrub, and forb species seeded with and without indaziflam. We established the study as a split plot design (+/- indaziflam) with four replications of each species. We applied indaziflam treatments in July 2019 at 73 g ai ha^{-1}. We seeded species in either November 2019 or March 2020 based on each species' recommend planting timing. Plots were hand-weeded twice throughout growing season. We documented emergence in June and establishment in October 2020. Indaziflam tolerance was variable among species but for all species indaziflam reduced emergence and establishment. Some species were unable to establish at all while others were unable only with indaziflam. Grass density overall was greater than other functional groups but individual species responses were comparable for some forbs. Shrub and forb data should be interpreted cautiously due to severe impact from grasshoppers.

Indaziflam Effects on Native Plants: General Hazard Analysis and Application to Northern Colorado Front Range. John Vickery*; Colorado Native Plant Society, Denver, CO (019)

Indaziflam has become a valuable tool for pre-germination applications to control cheatgrass species and other winter annual grasses in vegetated, noncrop areas, as well as more recently, in rangeland settings. A significant amount of both research-associated and larger-scale applications have occurred in recent years in the northern Colorado Front Range. In such settings, indaziflam is often applied with other herbicides to control annual grasses that have already germinated. Where there are significant populations of commonly targeted biennials such as knapweed and mullein species, as well as musk or other thistles, additional foliar-applied ingredients may be added to the mix. However, when combined with indaziflam, it is important to make both types of applications as early in the spring (or as late in the fall) as possible as limited by air and ground temperature. However, regardless of such adjustments to timing, negative impacts on non-target species can be expected for both the pre-germination and post-emergent active ingredients. Native species that are most likely to be impacted by indaziflam are those: 1. that have relatively frequent or annual recruitment; and 2. those with shorter seed longevity (shorter persistence in the seed bank). The former largely consists of annual, biennial and possibly some short-lived perennial species. The latter group is not as simply characterized; but perhaps paradoxically, in aridlands and grasslands, perennial plants tend to have seeds with shorter soil longevity than annuals and biennials. Thus, although annuals typically germinate in more years than do perennials, they are not more dependent on frequent, successful years for long-term survival. There are very few native winter annual and semi-evergreen grass species here. However, the post-emergent products for treating cheatgrass are either non-selective (namely, glyphosate) or semi-selective (certain ALS inhibitor compounds). Similarly, winter annual forbs constitute an extremely small portion of the native plant complement. Thus, the potential concern with respect to the post-emergent actives lies with: 1. those plants with exposed photosynthetic tissue; 2. plants with unprotected (lacking bark) perennial stems or other live, but not necessarily photosynthesizing tissue (flower & leaf buds). The first group consists of biennial forbs, semi-evergreen forbs and graminoid species, cacti and conifers. The second includes most shrub species (the upper portions of which lack bark), *Rosa*, *Rubus* and other species with semi-woody stems, and (the very few) forb species with perennial stems. Little mortality is expected among the susceptible perennial forbs because of the limited 'exposure' and/or the relatively low application rates needed to control the targeted biennials (similarly with respect to woody and semi-woody plants and cacti). Little additional mortality is expected among annual forbs due to: the absence of native winter annuals, the early/pre-emergence timing of the application, and the fact that many or most species would have succumbed to the indaziflam). This leaves the relatively small number of monocarpic (biennial and otherwise) species as the group most likely to be negatively affected by the foliar treatments. In native plant communities, weed management practitioners need detailed guidance in order to integrated all of the important considerations outlined here. Indaziflam use can also take place concurrent with restoration projects by careful selection of the species planted by seed. Product labels identify some tolerant species and recent field experience has identified additional possibilities. Newly developing activated carbon technologies may be useful in increasing the native plant restoration palette. In the more significant natural settings, botanists and plant ecologist should often be involved in order to make more judicious decisions regarding specific application areas, methods, and targets vis-à-vis a more in-depth knowledge of the native species complement, their natural history and the context-specific conservation concerns. However, it should be recognized that in the presence of high cheatgrass densities, native plant recruitment and persistence will be severely diminished and with time, significant ecological shifts can be expected. Furthermore, due to the ecology and survival strategies of our aridland flora, relatively few native species are expected to experience more than temporary set backs due to the herbicide regimens discussed herein. However, because of our still modest level of experience with this active ingredient in natural settings, some level of caution and scrutiny may still be advised.

African Mustard Response to Treatment Over Time. Natalie L. Fronk*, Corey V. Ransom; Utah State University, Logan, UT (020)

African mustard is an invasive annual mustard found throughout the Sonoran and Mojave deserts. Because African mustard is a relatively recent invader in Utah with limited distribution, it is a high priority for weed management in both public and private lands. To provide management options for stakeholders, field trials were established in 2017, 2018, and 2019 to evaluate herbicide combinations, rates, and timings. Treatments were applied to 3 by 9 m plots arranged in a randomized complete blockdesign replicated four times. The three trials included fall and early winter applications of indaziflam, spring applications of metsulfuron, a low and high rate of 2,4-D, spring and fall applications of imazapic, and 2,4-D with indaziflam. All treatments in all three trials provided excellent control of African mustard 2 months after the spring treatment. In the 2017 and 2018 trials, the three highest rates of indaziflam maintained 100% control 15 months after the spring treatment, and 26 months after the 2017 spring treatment, the best residual control was found in plots with the two highest rates of indaziflam. Plots treated with 2,4-D, a foliar herbicide, maintained some control 2 years following treatment, indicating the importance of preventing seedbank supplementation in management. Second and third year control was variable between trials for other treatments in response to variation in precipitation and other climatic elements. In conclusion, a variety of management options are available with the potential to maintain levels of African mustard control into the third year after the initial application.

Control of Russian Knapweed by Aminopyralid, Clopyralid, and Quinclorac Delayed by Insufficient Precipitation. Boyd M. Kitchen*[1], Corey V. Ransom[2]; [1]Utah State University, Vernal, UT, [2]Utah State University, Logan, UT (021)

Two trials were initiated to test herbicide control of Russian knapweed near Randlett, Utah in 2017. The purpose of the first trial was to compare duration of control as influenced by aminopyralid rate and timing. The purpose of the second trial was to compare horticultural herbicides to aminopyralid and clopyralid for Russian knapweed control. Horticultural products included quinclorac and 2,4-D alone and various pre-mixture combinations (3 or 4 actives) of some of the following herbicides; 2,4-D, dicamba, MCPA, mecoprop, triclopyr, pyraflufen, and quinclorac. Both trials included summer and fall treatments. Summer applications were made June 20, 2017 and fall applications on November 19, 2017. All treatments were applied with a CO2-pressurized back pack sprayer delivering 18 gpa at 30 psi. Plots measured 10 X 30 feet and were replicated 4 times. When evaluated one year post-treatment, the best treatments were summer applied clopyralid or aminopyralid at full labeled rates with 70-80 percent control. When evaluated two years post-treatment, control increased significantly. Overall control was less than expected based on past research. Precipitation following the treatments was scarce, 3.81 inches in the 12 months following the summer treatments. More than half of that precipitation fell between the summer and fall treatments with less than 2 inches falling in the next nine months. During the second year after treatments, precipitation was 9.2 inches. Our conclusions were: reduced rates of aminopyralid did not give effective control; droughty conditions reduced control with aminopyralid and clopyralid in the year following treatment; control improved the second year with increased precipitation; quinclorac is labeled for use in turf and shows promise to suppress Russian knapweed when applied in the summer; none of the horticultural herbicide pre-mixtures were effective.

WSWS Project 2. Weeds of Horticultural Crops

Bicyclpyrone Use Patterns in Minor Crops. Pete Forster*[1], Scott Payne[2], Timothy Trower[3], Eric Rawls[4], Tom Beckett[5], Pete Eure[5]; [1]Syngenta Crop Protection, Eaton, CO, [2]Syngenta Crop

Protection, Slater, IA, [3]Syngenta Crop Protection, Baraboo, WI, [4]Syngenta Crop Protection, Vero Beach, FL, [5]Syngenta Crop Protection, Greensboro, NC (022)

Bicyclopyrone is an HPPD-inhibitor (Group 27) herbicide and is one of the active ingredients in Acuron® herbicide. Syngenta is currently pursuing registrations in sixteen minor use crops: banana, plantain, papaya, pineapple, rosemary, lemongrass, broccoli, garlic, hops, horseradish, sweet potato, bulb onion, green onion, timothy grown for seed, strawberry, and watermelon. The application rate ranges from 37.5 to 50 g ai ha^{-1}. Bicyclopyrone offers a great deal of versatility in application methods including preplant, preemergence, pre-transplant, row middle, post-directed, and postemergence, depending on crop. Crop tolerance to bicyclopyrone varies by crop, application rate, and application method. Directions for use include not exceeding 50 g ai ha^{-1} bicyclopyrone per acre per crop year, not exceeding one application per year, adding a nonionic surfactant at 0.25% v/v or crop oil concentrate at 1% v/v for postemergence applications. Soil applications will provide 3-4 weeks of residual control or partial control of several grass and broadleaf weeds. Postemergence applications of bicyclopyrone to 5 cm-tall or shorter weeds will provide control or partial control of several grass and broadleaf weeds. Bicyclopyrone will provide for an additional active ingredient, and in some cases, a new site of action for managing herbicide-resistant weeds in crops with limited weed control options.

***Humulus lupulus* Response to Tiafenacil and Tolpiralate.** David R. King, Ryan Jacob Hill, Marcelo L. Moretti*; Oregon State University, Corvallis, OR (023)

Chemical weed control is the primary weed control method in hops (*Humulus lupulus*) in the USA. Despite its importance, a limited gamut of POST is registered for *H. lupulus*. Field experiments were conducted to evaluate tiafenacil, an inhibitor of protoporphyrinogen oxidase IX, and the 4-hydroxyphenyl pyruvate dioxygenase inhibitor, tolpyralate. Crop safety was evaluated with the herbicides applied two- or six-weeks after *H. lulupus* training or sequential application. Selected tank-mixtures were included. Tiafenacil at 50 to 100 g ai ha^{-1} was safe to *H. lupulus* cv 'Meridian' and 'Mount Hood' at both application timings tested. Crop height and yield were not impacted by tiafenacil compared to a nontreated control, even when sequential applications resulted in 200 g ai ha^{-1}. Tolpyralate applied at 39 and 78 g ai ha-1 two weeks after training resulted in 40 to 58% injury, respectively. When applied six weeks after training, tolpyralate resulted in less than 13% injury and did not impact crop height or yield. A tank-mix of tolpyralate with tiafenacil reduced crop injury compared to a tiafenacil application alone. These herbicides have the potential for future registration in *H. lulupus.* Additional trials will be conducted in 2021.

Tree and Vine Crop Sensitivity to Florpyrauxifen-benzyl in California. Deniz Inci*, Kassim Al-Khatib, Brad Hanson; University of California, Davis, CA (024)

Approximately a half-million acres of flooded rice is grown in the Sacramento Valley, a region which also produces a variety of orchard and vine crops. California rice production relies on complex herbicide programs to ensure maximum rice yield and quality and these are often applied by aircraft. Florpyrauxifen-benzyl is a new picolinic acid herbicide anticipated to be registered in rice for the 2021 growing season. This study was conducted to develop data on tree and vine crop sensitivity to simulated drift rates of florpyrauxifen-benzyl to preemptively inform stewardship programs for this herbicide. Newly planted almond, peach, pistachio, prune, and walnut as well as an established vineyard were treated with 0.5%, 1%, 3%, and 10% of the full rate in rice (29.4 g ai ha^{-1}) to simulate a drift scenario in mid-June 2020. Florpyrauxifen-benzyl symptoms were apparent on all tree species; visual injury increased as the rate increased. However, the speed and severity of the symptoms were greatest on pistachio compared to the other tree crops. Pistachio symptoms included general chlorosis, chlorotic spots, leaf curling, leaf narrowing, leaf distortion, leaf malformation, leaf crinkling, shoot curling, stem coloring, stunting, terminal bud death, and twisting. Even though all crops evaluated were injured by the simulated drift of florpyrauxifen-benzyl, most crops recovered and resumed growth later in the season. Pistachio injury was the most severe and persisted for the remainder of the growing season. Crop injury effects will be evaluated at leaf-out in spring 2021 and treatments reapplied for a second growing season.

Efficacy and Safety of Topramezone for the Control of Summer Grass Weeds in Turf. Kai Umeda*; University of Arizona, Phoenix, AZ (025)

During the summer of 2020, five field experiments were conducted to evaluate the efficacy of topramezone (Pylex herbicide) against southwestern cupgrass (*Eriochloa gracilis*), crabgrass (*Digitaria* spp.), and goosegrass (*Eleusine indica*) in bermudagrass turf. Topramezone can selectively control summer annual grass weeds in warm-season bermudagrass turf while also being able to selectively control bermudagrass in cool-season turfgrasses. The margin of safety is very narrow to control cupgrass, crabgrass, and goosegrass with the typical occurrence of phytotoxicity in the form of bleaching on bermudagrass turf. Topramezone at rates ranging from 0.011 to 0.033 lb a.i./A was applied with methylated seed oil or in a tank-mix with zinc sulfate ($ZnSO_4$) or with other herbicides to compare the relative phytotoxicity or safety on bermudagrass turf and efficacy on weeds. Topramezone at 0.016 and 0.033 lb a.i./A were effective against both crabgrass and southwestern cupgrass within a week of application and optimal weed control was observed within 2 weeks. The higher rate tended to be more active and weed control lasted slightly longer. The addition of quinclorac in a tank-mix did not enhance weed control efficacy. The addition to topramezone of $ZnSO_4$ at 16 lb/A reduced efficacy against cupgrass. Goosegrass control was achieved with topramezone at 0.011 and 0.016 lb a.i./A. A single application in June gave near complete control at 3 weeks after the application. Sequential applications in July gave acceptable control at better than 80% and the addition of $ZnSO_4$ to topramezone at 0.016 lb a.i./A was comparable to topramezone at 0.011 lb a.i./A. Tank-mixing topramezone with $ZnSO_4$, carfentrazone + 2,4-D + dicamba + MCPP, or metribuzin did not appear to enhance or reduce goosegrass control. A significantly high degree of bleaching lasted for over 2 weeks with a May application of topramezone. The addition of quinclorac did not reduce the onset of bermudagrass turf injury. June or July applications of topramezone with $ZnSO_4$ showed reduced bermudagrass turf injury and faster recovery at under 2 weeks. Tank-mixing topramezone with carfentrazone + 2,4-D + dicamba + MCPP, or metribuzin significantly reduced turf injury.

WSWS Project 3. Weeds of Agronomic Crops

Resistance Fighter: Local Partnerships Drive Better Herbicide Recommendations. Marty Schraer*[1], Dane L. Bowers[2], Pete Eure[2], Marshall Hay[3], Ethan T. Parker[3]; [1]Syngenta Crop Protection, Meridian, ID, [2]Syngenta Crop Protection, Greensboro, NC, [3]Syngenta Crop Protection, Vero Beach, FL (026)

Herbicide resistance is a global challenge in which all stakeholders in the agricultural community have an inter-related role to play. WSSA best management practices indicate that a strong herbicide program utilizing multiple effective sites of action should be combined with cultural and mechanical strategies as part of a comprehensive integrated weed management program. Herbicide resistance not only has implications for weed management but alters cropping systems, limits soil conservation practices, and reduces farm profitability. In the United States, there are approximately 575 unique cases of species by herbicide by state herbicide resistances across 85 species. Due to the complexity of the challenges associated with herbicide resistance, it has been described as a 'wicked problem' with no clear causes or solutions. While the weed science community does understand some of the major causes of resistance and probable solutions, the challenge continues at a global scale. As a manufacturer and registrant of active ingredients as well as herbicide formulations, Syngenta developed the Resistance Fighter® brand to communicate our commitment to good resistance management practices. Syngenta utilizes this brand in the development of new herbicides as well as with our industry leading sales and agronomic support in the field. Syngenta's unique commitment to deliver products with and through local retailers aligns with the Resistance Fighter brand. This enables a direct channel of communication from Syngenta through the retail to the producer. Because producers are the ultimate customer and must find balance between sustainable practices and economic constraints, the Resistance Fighter brand is critical to help engage in these discussions. Furthermore, Syngenta partners with University Research and Extension personnel to understand how to make the best management recommendations. Because of Syngenta's commitment to the customer, if a retailer reports a field failure, the local sales and agronomy team visits the site and engages in discussion with the retailer and producer. If herbicide resistance is suspected, samples are collected and sent to Syngenta's state-of-the-art Vero Beach Research Center in Vero Beach, FL. Suspect resistant samples may be subject to molecular marker assays or traditional greenhouse dose response with the herbicide of interest. Multiple known resistant and susceptible biotypes are included with all tests to aid in the interpretation. The results from molecular assays and greenhouse dose response are conveyed to the field. While traditional dose response alone does not provide a genuine confirmation, it serves as the basis for future work at the field level. Syngenta partners with the retailer and producer to use the results from the resistance samples to tailor solutions to each field. Too often, broad recommendations about resistance profiles are assumed which may sideline key herbicide tools. Syngenta's Resistance Fighter approach brings maximum value to each farm. Furthermore, Syngenta agronomists utilize regional Grow More™ Experiences to help producers visually see how to incorporate a sound herbicide program into an integrated weed management plan with cultural or mechanical controls. Syngenta's strong relationships with University partners are often engaged when novel or complex resistance challenges are identified to help develop the best strategy.

Weed Suppression Versus Water Use: Can Cover Crops be Sustainable in Water Limited Agroecosystems? Prashasti Agarwal*, Erik A. Lehnhoff; New Mexico State University, Las Cruces, NM (027)

Winter cover crops (WCCs) may facilitate weed management by inhibiting weed seed germination, seedling emergence and suppress weed growth within the cash crop. In New Mexico, with scarce winter precipitation and limited irrigation water, producing sufficient cover crop biomass for effective weed suppression while conserving water resources for subsequent cash crop growth is challenging. This study assessed the minimum water required to produce optimum WCC biomass for weed management benefits during cash crop growth. Monocultures of three WCC species, barley (*Hordeum vulgare*), Austrian winter peas (*Pisum sativum* subsp. *arvense)* and mustard (*Brassica juncea* var. Caliente 199) and a three-way mix, under three differential irrigation treatments were evaluated for their weed suppressive potential. Dry fallow served as conventional control. Split-plot design with irrigation as main-plot factor and WCC species as the sub-plot factor was used. Sweet corn (*Zea mays*) was planted as cash crop four weeks after WCC termination. Irrigation had no effect on WCC biomass. All WCCs had lower weed density prior to corn planting than dry fallows, which decreased exponentially with an increase in biomass. The effect of WCCs on weed suppression diminished during corn growth suggesting that even though WCCs offered some pre and early season weed control, they did not suppress weeds throughout the season. More importantly, all WCCs except barley yielded as much sweet corn as the dry fallows. Overall, our results showed that one supplemental irrigation might be enough to produce sufficient WCC biomass for weed suppression without compromising cash crop yield in New Mexico.

Palmer Amaranth Interference and Seed Production in Dry Edible Bean. Joshua Wa Miranda Teo*[1], Jeff Bradshaw[1], Amit J. Jhala[2], Nevin Lawrence[1]; [1]University of Nebraska, Scottsbluff, NE, [2]University of Nebraska, Lincoln, NE (028)

Palmer amaranth has become prevalent in Western Nebraska in the past five years. Palmer amaranth is characterized by season-long emergence, fast growth, high seed production, and is commonly resistant to multiple herbicide sites of actions. A field study was conducted in Scottsbluff, NE in 2020 to quantify the impact of season-long Palmer amaranth interference in dry edible bean at different densities. Plots were established using naturally occurring Palmer amaranth plants at fixed density levels: 0, 0.2, 0.3, 0.5, 1, and 2 plants m^{-1} row. Response variables included dry edible bean yield, dry edible bean yield components, and Palmer amaranth seed production. Non-linear regression analyses were used to model all response variables. Palmer amaranth reduced dry edible bean yield by 86% at the highest density level tested, and 50% yield reduction is estimated to occur at 0.37 plants m^{-1}. Yield reduction was attributed to the reduction in dry edible bean yield components, principally a reduction in the number of pods $plant^{-1}$ as Palmer amaranth density increased. Palmer amaranth produced 107,000 to 297,000 seeds $plant^{-1}$ and 12,000 to 159,000 seeds m^{-2}. To avoid yield loss, integrated weed management approaches must be applied to control Palmer amaranth given the severe crop yield reduction and high Palmer amaranth seed production observed at low densities.

Sulfosulfuron for Control of Roughstalk Bluegrass in Kentucky Bluegrass Seed Crops. John F. Spring*[1], Richard P. Affeldt[2], [1]Central Oregon Agricultural Research & Extension Center, Oregon State University, Madras, OR, [2]Central Oregon Seed, Inc., Madras, OR (029)

Primisulfuron has been critical for control of the important seed contaminant roughstalk bluegrass in Kentucky bluegrass grown for seed but is not currently available. Over the 2020 crop year, sulfosulfuron was evaluated for this use in small plot-field trials (randomized complete block design, 4 replicates, individual plot size 3 x 9 m) at 4 locations in new seedlings of irrigated Kentucky bluegrass in central Oregon. Sulfosulfuron was applied in the fall only (13, 20, 40 g ai ha^{-1}), spring only (13, 20, 40 g ai ha^{-1}), and fall + spring split applications (13 + 13, 20 + 20, 13 + 20, 20 + 13 g ai ha^{-1}), compared to the industry standard use of primisulfuron (fall + spring split application of 20 + 20 g ai ha^{-1}). Fall-only applications of sulfosulfuron provided crop safety and seed yield equivalent to the industry standard primisulfuron, while spring-only and fall + spring split applications had unacceptably high crop injury (mean injury > 20%) at early boot stage, and slightly reduced seed yield (3 to 5%) in well-managed fields. Split applications at all but the lowest rate gave acceptable control of roughstalk bluegrass (95 to 96%) relative to the standard primisulfuron (91%), as did fall-only sulfosulfuron at 40 g ai ha^{-1} (98%). Fall-only sulfosulfuron at 20 g ai ha^{-1} and the split of 13 g ai ha^{-1} in both fall + spring gave intermediate control (84 and 82%, respectively). Spring-only applications gave poor control at all rates (40 to 44%), as did fall-only sulfosulfuron at 13 g ai ha^{-1} (56%). When applied in the fall at 40 g ai ha^{-1}, and possibly at 20 g ai ha^{-1}, sulfosulfuron offers a viable alternative to primisulfuron for control of roughstalk bluegrass in Kentucky bluegrass seed production.

Lactofen Efficacy as Affected by Increased Temperature in PPO-Inhibitor-Resistant and -Susceptible Palmer Amaranth (*Amaranthus palmeri*). Ednaldo A. Borgato*, Anita Dille, Mithila Jugulam; Kansas State University, Manhattan, KS (030)

Palmer amaranth (*Amaranthus palmeri* S. Watson) has a wide window of emergence throughout the cropping season, requiring multiple herbicide applications to maximize control. However, early- and late-post-emergence applications can occur during times of stressful environmental conditions, such as high temperatures, which are known to reduce efficacy of several herbicides. This study investigated the effect of temperature stress on lactofen efficacy in PPO-inhibitor-resistant (R) and -susceptible (S) Palmer amaranth. Plants were grown in growth chambers maintained at 14 hours day length and relative humidity at 70%. Two temperature regimes, i.e., optimum (OT; 30/20 C d/n) and high (HT; 40/30 C d/n) were maintained in two separate growth chambers. Eight-10 cm tall plants were treated with lactofen doses ranging from 0 to 438 g ai ha^{-1} for S and 0 to 1752 g ai ha^{-1} for R. Survival data was assessed 2 weeks after treatment and analyzed using log-logistic model to determine the dose required for 50% of mortality (LD_{50}). Results indicate that the S plants did not show any variation in LD_{50} in response to temperature stress. Interestingly, LD_{50} increased significantly in R plants at HT compared to OT. This preliminary data suggest that the efficacy of lactofen is not likely affected by temperature stress in S Palmer amaranth. But HT stress can significantly reduce the activity of lactofen in R plants. Future work will include the investigation of physiological basis contributing to reduced efficacy of lactofen in R Palmer amaranth under temperature stress.

Metabolism of Fluroxypyr in Fluroxypyr-ALS Resistant Kochia from Eastern Colorado. Olivia E. Todd*, Todd A. Gaines; Colorado State University, Fort Collins, CO (031)

A population of kochia from eastern Colorado, Flur-R (fluroxypyr resistant), was investigated for metabolic resistance to fluroxypyr. Twenty-four plants each of the resistant and susceptible (J01-S) populations were treated with non-radiolabeled fluroxypyr at the label rate (157 g ae ha^{-1}) and the third meristem leaf was treated with 0.5 µCi [^{14}C]-fluroxypyr ester when the plant was 3 to 4 cm in height. After washing the treated leaf, whole plant metabolite extraction was conducted at 6, 12, 24, 48, 96 and 192 hours after treatment. Using High Pressure Liquid Chromatography (HPLC) we identified the retention times of [^{14}C]-fluroxypyr ester and [^{14}C]-fluroxypyr acid. Four additional peaks were identified to be fluroxypyr metabolites. We found that Flur-R had a greater difference in total metabolite production at 12 and 24 HAT. Metabolites two, three and four were produced more by Flur-R within the 12 to 24 HAT timeframe, but also showed differences at 96 and 192 HAT. Metabolite three was produced by J01-S at a significantly higher level at 96 and 192 HAT. These results suggest that metabolites two and four, produced in higher amounts in Flur-R at 4 to 8 days after treatment, may represent less phytotoxic or inactive metabolites as part of a metabolic resistance mechanism.

CoAXium Wheat Variety Tolerance to Quizalofop in the Southern Great Plains. Caitlyn C. Carnahan*[1], Misha R. Manuchehri[1], Vipan Kumar[2], Brett F. Carver[1], Hannah C. Lindell[1], Lane S. Newlin[1], Justin T. Childers[3]; [1]Oklahoma State University, Stillwater, OK, [2]Kansas State University, Hays, KS, [3]Oklahoma State University, Marlow, OK (032)

CoAXium Wheat is a relatively new herbicide tolerant system that provides POST control of many winter annual grass species. However, crop tolerance concerns have been raised by agricultural stakeholders in the state of Oklahoma, especially when applications are made near wheat jointing. To evaluate the response of various varieties of wheat that contain the AXigen trait to quizalofop-P-ethyl, a study was conducted at Perkins and Tipton, Oklahoma and Hays, Kansas. Regionally adapted varieties included Crescent AX, Fusion AX, Photon AX, Helix AX, and AP18 AX. One herbicide treatment (92 g a.i. ha^{-1} of quizalofop-P-ethyl plus MSO at 1% vol/vol) was applied at three timings (fall, early spring, and late spring). When evaluating visual injury and biomass at all locations, there was no wheat variety by herbicide interaction. For visual injury at Perkins, there was a variety main effect where variety AP18 AX exhibited the highest level of damage at 7% while Helix AX, Photon AX, and Fusion AX were similar. Crescent AX showed the least crop injury (1%) but was not different than Fusion AX (2%). Finally, for biomass at Perkins and Tipton, there was a herbicide main effect where compared to the nontreated control, biomass for fall treated plots was reduced by 17% at Perkins and 13% at Tipton. Significant wheat injury was not expected for the fall application. However, injury is anticipated to increase following early spring and late spring applications.

Evaluation of ALS- and ACCase- Inhibiting Herbicides for Green Foxtail Control. Rui Liu*[1], Vipan Kumar[1], Isaac N. Effertz[2], Taylor Lambert[1]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Manhattan, KS (033)

Due to the lack of effective herbicide options, in season control of grass weed species in sorghum production in the Great Plains region is challenging. Recent development of herbicide-resistant sorghum technologies, such as Inzen™, Igrowth™, and Double Team™, will allow the use of POST applications of nicosulfuron, imazamox, and quizalofop-p-ethyl, respectively, for grass control in sorghum. Studies were designed with the three objectives to: 1) compare the efficacy of PRE- applied imazamox with three commonly used group 15 herbicides for grass control; 2) determine the effectiveness of nicosulfuron, imazamox, and quizalofop-p-ethyl applied EPOST and LPOST at two different rates for grass weed control; 3) test the compatibility of nicosulfuron, imazamox, quizalofop-p-ethyl, clethodim tank-mixed with 2, 4-D or dicamba for grass weed control. Two separate experiments were conducted in fallow fields with corn stubble and natural infestation of green foxtail at Kansas State University Agricultural Research Center at Hays, KS, in 2020. Both experiments used randomized complete block design, with four replications. In experiment 1, herbicides imazamox (53 and 78 g ha^{-1}), s-metolachlor (1604 g ha^{-1}), acetochlor (1680 g ha^{-1}), and dimethenamid-P (945 g ha^{-1}) applied PRE, and herbicides imazamox (53 and 78 g ha^{-1}), nicosulfuron (36 and 54 g ha^{-1}), and quizalofop-p-ethyl (46 and 88 g ha^{-1}) applied both early- and late- POST (EPOST, LPOST) were tested. In experiment 2, herbicides imazamox, nicosulfuron, quizalofop, and clethodim alone or tank-mixed with 2, 4-D/ dicamba applied EPOST were tested. The PRE, EPOST, and LPOST programs were applied on April 16, June 4 (green foxtail at 8 to 10 cm height), and June 24 (green foxtail at 30 cm height), respectively, in 2020. Data collected include biweekly percent control of green foxtail throughout the season and end of the season aboveground green foxtail shoot biomass. Results from experiment 1 showed that imazamox at both rates were able to provide excellent control (89 to 94%) of green foxtail till 50 days after PRE application (DAPRE). The other three PRE treatments provided control lower than 51%. Quizalofop-p-ethyl at 88 g ha^{-1} provided 95% control of green foxtail at 28 days after EPOST (DAEPOST), which was the best among all of the EPOST programs. All of the LPOST programs did not provide satisfactory control of green foxtail, with the percent control at 21 days after LPOST (DALPOST) ranged from 14 to 31%. Similarly, EPOST applied quizalofop-p-ethyl at 88 g ha^{-1} had the highest green foxtail shoot biomass reduction (78%). Experiment 2 results showed that 2, 4-D or dicamba in tank-mixture with quizalofop-p-ethyl reduced green foxtail control by >50% comparing to quizalofop-p-ethyl applied alone. These preliminary results can provide guidance to the use of herbicide programs in Inzen™, Igrowth™, and Double Team™ sorghum technologies in the future.

State of Herbicide-Resistant Palmer Amaranth in Kansas. Vipan Kumar*, Rui Liu, Taylor Lambert, Phillip W. Stahlman; Kansas State University, Hays, KS (034)

Herbicide-resistant (HR) Palmer amaranth and common waterhemp are serious management challenge for Kansas growers. Since 2014, an ongoing field survey to collect seeds of both weed species from agronomic crops to determine the frequency and distribution of herbicide resistance in Kansas is underway. The main objective of this research was to determine the resistance frequency (as percent survival frequency within a population) in 20 Palmer amaranth and 29 waterhemp populations from Kansas fields to discriminate dose of glyphosate, 2,4-D, glyphosate + 2,4-D choline premix (Enlist Duo®), dicamba, glufosinate, fomesafen, atrazine, and chlorsulfuron. Seedlings from Palmer amaranth and common waterhemp populations were grown in 5- by 5-cm size cells within a plastic tray (total 50 cells $tray^{-1}$) filled with a commercial potting mix in a greenhouse at Kansas State University Agricultural Research Center (KSU-ARC) near Hays, KS. Actively growing seedlings (7- to 9-cm tall) from each population were separately treated with discriminate dose of glyphosate (1260 g ha^{-1}), 2,4-D (870 g ha^{-1}), glyphosate + 2,4-D choline (1071 + 1008 g ha^{-1}), dicamba (560 g ha^{-1}), glufosinate (655 g ha^{-1}), fomesafen (395 g ha^{-1}), atrazine (1120 g ha^{-1}), and chlorsulfuron (26 g ha^{-1}). Data on dead and live counts from each population and herbicide were recorded at 21 days after treatment (DAT) and converted into % survival frequency. Based on 20% survival frequency cutoff, resistance to glyphosate, 2,4-D, glufosinate, mesotrione, fomesafen, atrazine, and chlorsulfuron was observed in 12, 7, 13, 18, 9, 20 and 18 Palmer amaranth populations (out of total 20 populations) with resistance frequency of 20 to 80%, 20 to 30%, 22 to 44%, 24 to 64%, 20 to 67%, 24 to 76% and 25 to 65% respectively. None of the tested Palmer amaranth populations showed resistance frequency of >7% and >11% with a discriminate dose of dicamba and glyphosate + 2,4-D, respectively. Similarly, putative resistance to glyphosate, glufosinate, mesotrione, fomesafen, atrazine, and chlorsulfuron was observed in 29, 4, 16, 10, 22, and 29 waterhemp populations (out of total 29 populations) with resistance frequency of 33 to 100%, 21 to 51%, 23 to 100%, 31 to 68%, 27 to 98%, and 22 to 100% respectively. Only 1 and 3 out of 29 total waterhemp populations showed putative resistance to dicamba (33% survival frequency) and 2,4-D (21 to 30% survival frequency). These results suggest that resistance to commonly used herbicides (glyphosate, mesotrione, fomesafen, atrazine, and chlorsulfuron) is evident in Palmer amaranth and waterhemp populations in Kansas. Furthermore, putative resistance to 2,4-D and fomesafen among Palmer amaranth populations is in the early stage of evolution. Growers should adopt diversified weed control strategies to tackle the problem of HR Palmer amaranth and common waterhemp.

***Amaranthus palmeri* Interference in Sugar Beet.** Whitney R. Frazier*, Nevin Lawrence; University of Nebraska, Scottsbluff, NE (035)

Glyphosate-resistant Palmer amaranth is becoming more common in the sugar beet production area of Western Nebraska. Currently, there are no herbicide options that are effective for control of Palmer amaranth. The competitive ability of Palmer amaranth in sugar beet has not been previously quantified. Therefore, a three-year study was carried out in Scottsbluff, NE to measure the impact of season-long Palmer amaranth competition in sugar beet. In 2018, Palmer amaranth densities were 0, 0.5, 1, 2, 4, and 8 plants row^{-1}. In 2019 and 2020, Palmer amaranth densities were 0, 0.2, 0.3, 0.5, 1, and 2 plants row^{-1}. All years had a row spacing of 56 cm. The study was designed as a RCBD with four replicates, with plot dimensions of 2.2 m by 9.1 m. Response variables included sugar beet yield, estimated recoverable sugar, sugar beet yield loss, and Palmer amaranth seed production $plant^{-1}$ and m^{-2}. Regression analysis was used to estimate the impact of Palmer amaranth competition with sugar beet. A Michaelis-Menten model was used to estimate sugar beet yield loss and a log-logistic model was used to estimate all other response variables. The estimated Palmer amaranth density to cause 50% yield loss in sugar beet was 0.06 and 0.79 plants m row^{-1} in 2018 and 2019, respectively. In 2020, yield loss was not observed at the lowest density levels and a regression model could not be fit. Seed production ranged from 2,700 to 523,300 $plant^{-1}$ and 6,700 to 2,800,000 m^{-2} across years and Palmer amaranth densities.

Population Dynamics of Weedy Rice (*Oryza sativa* f. *spontanea*) in a California Rice Field.
Whitney Brim-DeForest*[1], Luis Espino[2]; [1]University of California Division of Agriculture and Natural Resources, Yuba City, CA, [2]University of California Division of Agriculture and Natural Resources, Oroville, CA (036)

Weedy rice (*Oryza sativa* f. *spontanea*) is a relatively new weed species in California rice. Five phenotypically and genetically distinct biotypes were identified in 2016, with differing characteristics, in terms of dormancy and early growth. A field experiment was conducted in 2019 and 2020 comparing weedy rice emergence under two irrigation regimens. The objectives of this experiment were to determine under field conditions: 1) If California weedy rice biotypes emerge under both flooded and flushed irrigation; 2) If there are differences in emergence patterns between the two irrigation systems; and 3) If there are differences in emergence patterns between seasons. A soil seedbank analysis was also conducted, but the data from 2020 is not yet processed. Before the start of this experiment, weedy rice Biotypes 1, 2, 3, and 5 were seeded into the plots (in the spring of 2018, 2019, and 2020). Soil samples were collected in the spring of 2019 and 2020, on transects through the center of each weedy rice plot (3, 9, 15, 21, 27, 33, and 39 m from the north end of the field). Cores were individually washed, rice seeds were extracted and then subjected to a potassium hydroxide (KOH) test, to determine if they were weedy. Two irrigation treatments were tested. Treatment 1, Continuous Flood (CF), was maintained with a 10-cm flood. Treatment 2, Stale Seedbed (SS) was lightly tilled in the spring, followed by a flush of water to allow weedy rice germination. Approximately 1 week after the initial flush, the field was flushed again. About 2 weeks after the initial flush, the field was flooded to 10 cm. To assess emergence, from the start of irrigation water application in the field, weedy rice counts were taken daily, from three rings (929 cm^2 each) placed in each plot. Temperature (°C) was logged hourly in each plot, and volumetric water content (cm^3 cm^{-3}) was also logged in the flushed plots. All weedy rice biotypes emerged under both flooded and flushed conditions, with a larger percentage of all types emerging under flushed conditions. In the CF, emergence started around 8 days in 2019, and around 24 days in 2020. In the SS, emergence started around 9 days in 2019, and around 8 days in 2020. In 2019, about twice as many plants per square foot emerge under flushed conditions, compared to flooded, and in 2020, there was about a 10-fold increase in weedy rice plants under flushed versus flooded conditions, especially Biotype 3 and Biotype 1.

Kochia Control with Dichlorprop-P. Andrew R. Kniss*; University of Wyoming, Laramie, WY (037)

A field study was conducted near Lingle, Wyoming in 2020 to evaluate a commercial combination of dichlorprop-P + dicamba + 2,4-D (NUP 19051, Scorch EXT). The commercial product was applied at rates ranging from 12 fl. oz/A to 48 fl. oz/A. A standalone dicamba product (Clarity) and a standalone dichlorprop-P product (NUP 17063) were applied as a comparison to evaluate rate equivalence. Dicamba-resistant kochia was not present on the study site. The study was placed on dryland fallow with a heavy density of kochia. Herbicides were applied when kochia reached 10 cm height. Weed control was evaluated weekly up to 34 days after treatment (DAT). Kochia control with NUP 19051 was modeled with a 3-parameter log-logistic nonlinear regression, and the dose of NUP 19051 that provided the same level of control as Clarity at 10 fl. oz/A was estimated. NUP 19051 applied at 11 fl. oz/A provided similar kochia control as Clarity at 10 fl. oz/A. At the estimated commercial product rate equivalency, 10 fl. oz of Clarity contains less herbicide acid equivalent than 11 fl. oz of Scorch EXT. Dichlorprop-P alone at 0.5 lbs/A controlled kochia similarly to 0.31 lbs/A dicamba for approximately 20 days after treatment, after which kochia control decreased for dichlorprop-P. The commercial mixture of Scorch EXT at 0.5 lbs ae/A (12 fl. oz/A of product) provided equivalent control as 0.31 lbs/A of dicamba for up to 35 DAT.

Oat Tolerance to Soil- and Postemergence-Applied Herbicides. Brian Jenks*[1], Caleb D. Dalley[2]; [1]North Dakota State University, Minot, ND, [2]North Dakota State University, Hettinger, ND (038)

Several companies have announced contracting opportunities for tame oat *(Avena sativa L.)* in North Dakota. Many growers are interested in growing oat, but are concerned about how to control grass weeds. It is common for weedy grasses such as green foxtail, yellow foxtail, barnyardgrass, and wild oat to impact crop yield. It is not unusual for crop yields to be reduced 15-40% with heavy densities of foxtail and wild oat. This project evaluated oat tolerance to several herbicides applied either preemergence or early postemergence. An herbicide to control grasses in oat would be provide a significant boost to oat production. The study was conducted at two locations (2017-2020). The study objectives were to 1) evaluate oat tolerance to soil-applied herbicides and 2) evaluate oat tolerance to postemergence-applied herbicides at the 1-leaf or 4-leaf oat stage. Herbicides were applied preemergence (PRE) or postemergence (POST) at the 1-leaf or 4-leaf oat stage. Treatments included Zidua (pyroxasulfone), Warrant (acetochlor), Dual (metolachlor), Prowl (pendimethalin), Outlook (dimethenamid), Amezon (topramezone), and Laudis (tembotrione). The study was conducted using traditional small plot techniques with 3 or 4 replications. Oat injury was evaluated visually with 0=no injury and 100=completely dead. At Minot, Warrant and Dual generally caused less than 15% oat injury. Outlook caused less than 15% injury in 3 of 4 years, but 77% injury in one year. Prowl caused less than 15% injury in two years, but 30% injury in the other two years. Zidua caused moderate to severe injury in all years. Armezon applied at 1-leaf caused less than 15% injury, but caused significant injury at the 4-leaf stage in 2 of 4 years. Laudis caused 16% injury in the one year tested. At Hettinger, Warrant, Dual, Prowl, and Outlook caused very little injury in all four years. Zidua caused severe injury in 1 of 4 years. Armezon at 1-leaf caused moderate injury in 1 of 4 years, but caused moderate to severe injury in all four years at the 4-leaf stage. Laudis caused very little injury in the one year tested. Both locations experienced dry conditions in all years of the study except for Minot in June 2018 and Hettinger in 2019.

Organic Weed Management of Creeping Perennials Field Bindweed and Canada Thistle. Lydia S. Fields*, Rachel J. Zuger, Carol McFarland, Ian C. Burke, Ronald Sloot; Washington State University, Pullman, WA (039)

Creeping perennial weeds field bindweed (*Convolvulus arvensis*) and Canada thistle (*Cirsium arvense*) are problematic to agricultural fields for their persistence and vegetative regenerative ability. Organically managed fields have limited options for managing field bindweed and Canada thistle in transition or in organic production. Crop rotation may have potential to effectively control or suppress field bindweed and Canada thistle populations in organically managed systems. To determine the effectiveness of crop rotation at reducing creeping perennial weed populations, a four-year study was initiated in 2019, testing 5 different crop rotations. The objective of this study is to determine the impact of these five organic crop rotations on field bindweed and Canada thistle control, as well as crop performance and yield. Currently we are on year two of the four-year study and have compared 2020 Canada thistle biomass and weed density was assessed each year. Canada thistle biomass has been found to be generally lower in year two vs year one, and in decline in rotations that involve a mowing or swathing input. Perennial and annual weed densities varied by year and species. Canada thistle populations appear in decline in cover crop and forage treatments, but not in annual cropping rotations. Alfalfa rotations are effective for reducing overall Canada thistle infestations, and cover crops appear to be as effective in our work. Transitioning to organic production while managing Canada thistle may be achievable by cover cropping as an option to alfalfa.

Genetic Architecture of Flowering Time Traits in *Bromus tectorum* of the Pacific Northwest. Samuel R. Revolinski*[1], Ian C. Burke[1], Craig Coleman[2], Jeff Maughan[2]; [1]Washington State University, Pullman, WA, [2]BYU, Provo, UT (040)

Bromus tectorum L. is an invasive weed in the intermountain west. Adaptive traits such as flowering time are heritable in *B. tectorum*, however the underlying genes controlling these traits are unknown. Seeds of 121 collections, or genotypes, were grown in the greenhouse, vernalized, and allowed to flower so flowering time traits could be phenotyped. We identified 21 significant single nucleotide polymorphisms (SNPs) for height (cm), days to first visible panicle, days to first joint, days to first ripe seed and days to 50% ripe seed. Genes similar to the Heading Date Represor 1 (HDR1), Far-Red Elongated Hypocotyl 3 (FHY3), Far1-Related Sequence 6 (FRS6), Far1-Related Sequence 5 (FRS5), Dehydration-responsive element-binding protein 1F (DREB1F), Cullin-3A (CUL3A), Gibberellin 20 oxidase 2 (GA20OX2), and Phythochrome-Dependent Late-Flowering (PHL) were identified as potential candidate genes. A reference genome was assembled for future genomic studies of *B. tectorum*. The assembly was improved with all-paths contig creation and Omni-C scaffolding. The assembly was 2,482.01 Mbp long and has an N50 of 357.431 Mbp. There were 221 single copy Benchmarking Universal Single-Copy Orthologs (BUSCOs) discovered in the assembly. The genes discovered by the GWAS can be used for developing markers to for predicting flowering time and the mechanisms used *B. tectorum* to maintain genetic variation.

Gibberellic Acid as a Prospective Management Tool for Italian Ryegrass and Downy Brome in Eastern Washington. Madisyn R. Beaudoin*, Rachel J. Zuger, Ian C. Burke; Washington State University, Pullman, WA (041)

Winter annual grass downy brome (*Bromus tectorum* L.) and Italian ryegrass [*Lolium perenne* L. ssp. *Multiflorum* (Lam.) Husnot]) currently plague the dryland wheat production systems of the Pacific Northwest (PNW). Gibberellic acid (GA_3) is a plant growth hormone which can alleviate seed dormancy. Field studies were conducted to assess the response of downy brome and Italian ryegrass seedbanks to applications of GA_3 applied preemergence to winter wheat in mixtures or combinations of preemergence and postemergence treatments. Downy brome densities were assessed in the spring before and after postemergence treatment, while Italian ryegrass densities were assessed prior to harvest. Biomass was assessed in each trial prior to harvest. Preemergence treatments that include flumioxazin plus metribuzin, glyphosate and GA_3 as well as a postemergence treatment of pyroxsulam effectively controlled downy brome in winter wheat as assessed by density and biomass. Italian ryegrass control in winter wheat was greatest when preemergence applications of pyroxasulfone followed by pinoxaden or flumioxazin plus pyroxasulfone plus metribuzin GA_3 followed by postemergence applications of pinoxaden. Germination of both weed species was slowed by the coldest October on record, and additional experiments are needed to determine the impact of climate on the use of GA_3 for seedbank management.

Control of Mayweed Chamomile in Winter Pea with Bentazon Plus Acifluorfen. Kenton C. Lyman*, Madisyn R. Beaudoin, Lydia S. Fields, Ron Sloot, Derek Appel, Ian C. Burke; Washington State University, Pullman, WA (042)

Food grade winter peas are an emerging alternative crop in the wheat fallow production regions of the Inland Pacific Northwest (PNW). Weed management can be challenging due to limited selective herbicides, coupled with a protracted period without a canopy in early spring. Mayweed chamomile (*Anthemis cotula*) is an annual that germinates in the early spring and is particularly troublesome in winter pea. The objective of this experiment was to evaluate the crop safety and efficacy on mayweed chamomile using bentazon plus acifluorfen (Storm). The study was conducted as a randomized complete block with 4 replications in the spring of 2020, near Davenport WA. Treatments included Storm (560 g ai/ha 840 g ai/ha, 1680 g/ha) applied with nonionic surfactant at 0.25% or crop oil concentrate at 1.0%, MCPA (260 g ai ha^{-1}), or MCPA plus metribuzin (260 g ai ha^{-1} + 210 g ai ha^{-1}). Yield was quantified by harvesting aboveground biomass in two m^2 quadrats per harvestable plot. Although winter pea injury was transient, responses to Storm were characterized by reddish spots upon leaves that increased with herbicide rate and surfactant. Mayweed chamomile control decreased with increasing mayweed chamomile size, and the larger the plant the less likely Storm was to be lethal, regardless of rate. Although statistically similar, control of mayweed chamomile increased with the rate of Storm. Storm appears to be an effective and safe treatment for management of mayweed chamomile in winter pea.

Cutleaf Vipergrass: An Emerging Threat to Alfalfa Production and Rangeland. Jody A. Gale*[1], Corey V. Ransom[2], Nelson Mark[3], Cody J. Beckley[2]; [1]Utah State University - Extension, Annabella, UT, [2]Utah State University, Logan, UT, [3]Utah State University - Extension, Beaver, UT (043)

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WSWS Project 4. Teaching and Technology Transfer

Methods of Accounting for Sensor Uncertainty in Research and Decision-making. Dirk V. Baker*; Campbell Scientific, Inc., Logan, UT (044)

Automated instrumentation ranging from simple temperature loggers to extensive data acquisition systems provides invaluable tools to increase our understanding of abiotic factors in agricultural and ecological research. While these measurements have their own uncertainties (errors), these errors are rarely incorporated into analyses, conclusions, and recommendations in publications. The implicit assumption is that statistical error accounts for instrumentation error (or, worse, that there is no instrumentation error), but this assumption is, at best, untested, and it is likely that the two error sources are independent. In addition, there is often limited replication of instrumentation making direct estimations of error problematic. This is unfortunate, but understandable given budget constraints. There are several relatively straightforward methods of estimating measurement error and combining it with statistical error. Here, I will focus on two. The first and simplest is to use the manufacturer's error (accuracy) specifications and the variances to those of the statistical error. This is a conservative method and may overestimate total error, but it assumes a certain level of reliability and quality of manufacture. The second method is to perform a test or calibration of instrumentation prior to deployment to determine the actual uncertainty of the measurement for each sensor. This could be relative to each other or compared to an accepted standard with the latter necessary if inference to absolute numbers. Then the measured instrument uncertainty could be combined with statistical error with the first method. Failure to explicitly incorporate the contribution of uncertainty in automated measurements into analyses and, especially, conclusions carries with it unfounded assumptions that either the instrumentation error is accounted for or negligible compared to statistical error or that instrumentation error is zero. In making these assumptions, there is real risk in drawing conclusions of non-existent differences analogous to increasing the rate of type I statistical error. Proper estimation of this error allows for the advent of more informed statistical conclusions and more robust understanding of agricultural and ecological interactions and their abiotic dependencies.

Novel Methods to Teach Difficult Pest Control Concepts in Classroom and Extension Environments. Lance V. Stott*, Corey V. Ransom; Utah State University, Logan, UT (045)

Creative methods of safely demonstrating critical pest control concepts help learners to gain a more sound understanding of concepts that are otherwise difficult to visualize or conceptualize. Pesticide formulations, pesticide drift and pesticide equipment calibration are three such concepts. Many common food items have formulations similar to those used for pesticides. Kool-Aid, Nesquik and mayonnaise are three foods that can be used to demonstrate the differences between solutions, suspensions and emulsions. A simple demonstration of the preparation of these food products helps learners to conceptualize the different characteristics of these pesticide formulations and their mixing and agitation requirements. Pesticide drift is also difficult for learners to visualize. A portable wind tunnel constructed with a PVC pipe frame that can be clamped to any table top and covered with plastic provides a safe, concrete demonstration. Using water and a single spray nozzle in front of a fan, different scenarios of sprayer pressure and wind speed can be simulated. Water sensitive paper is used to collect droplets at intervals from the spray nozzle. Learners can participate in counting the drops on the papers to visualize how different sprayer settings and environmental conditions impact pesticide drift. Finally, equipment calibration is difficult to demonstrate safely in a classroom or conference. A miniature spray boom can be constructed with new parts and operated with water. Learners can then participate in the actual process of calibrating a sprayer without being exposed to pesticides. All of the procedures used to calibrate a sprayer can be demonstrated safely. Advancing technologies like electronic catch cups and nozzle patternators, can also be demonstrated. All of these methods help learners conceptualize pest control concepts that are otherwise difficult to demonstrate safely in public.

WSWS Project 5. Basic Biology and Ecology

Constructing a Synthetic EPSPS Copy Number Variation System to Assess Fitness and Glyphosate Resistance. Liliana Fendler*[1], Crystal D. Sparks[1], Eric L. Patterson[2], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Michigan State University, East Lansing, MI (046)

Through building a system to measure Enolpyruvylshikimate-3-phosphate synthases (EPSPS) over-expression on fitness, the system can help understand resistance mechanisms. Synthetic copy number variation is a way to demonstrate overexpression. CaMV35s have been used in biotechnology applications, but it is still not a stable practice. With climate shifts happenings, copy number variation could be a potential way to express new traits in round-up ready crops. Molecular cloning to make CNV of EPSPS and CaMV35s EPSPS has been completed, which can be used in a model to further understand the threshold of fitness results in overexpression. Through agrobacterium transformation in Arabidopsis, we hope to generate lines with multiple copies of EPSPS, with Colombia 0 (Col 0) and with the CaMV35s. Resulting in higher copy number lines through random insertion events and crossing over, ending with upwards of 40 copies. After upwards of forty copies have been attained, fitness assessments can be done to see how seed production, biomass, and dose response to glyphosate have been impacted. As seen in past publications, there is potential for a benefit from natural CNV, which can then be translated into crops. In turn this also means that if there is no glyphosate selection pressure, a mechanism of resistance could still be selected for. If we could demonstrate that there is no fitness penalty, this could have a strong agricultural impact by enhancing the already existing roundup ready technology.

Evaluating Phytohormone Response to Glyphosate Treatment in Rapid Response Giant Ragweed. Crystal D. Sparks*[1], Christopher Van Horn[2], Roland S. Beffa[3], Franck E. Dayan[1], Philip Westra[1], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Bayer CropScience, O'fallon, MI, [3]Bayer AG, CropScience Division, Frankfort / Main, Germany (047)

Two distinct glyphosate resistant biotypes of *Ambrosia trifida* (giant ragweed) have been identified, one of which displays a rapid cell death response in the mature leaves. The mechanism behind this response and resistance is currently unknown. Target site mutation, enhanced gene copy number and differential translocation have been experimentally rejected as the main mechanism of glyphosate resistance. The response in the mature leaves displays some similarities to pathogen response such as oxidative burst followed by rapid cell death. Changes in the signaling pathways involved in pathogen defense could explain the cell death phenomenon and perhaps provide a novel mechanism of glyphosate resistance. Here we use RNA-seq read counts normalized with the DESeq2 median of ratios method to evaluate expression of phytohormones that regulate pathogen defense. RNA-seq libraries from young and mature tissues of resistant and susceptible individuals, before and at three time points after glyphosate treatment have been sequenced for this analysis. We found that in general, jasmonic acid is up-regulated while salicylic acid is down-regulated, a pattern that could match their mutually antagonistic relationship in pathogen response. This analysis is ongoing and there is much more to be discovered about how these complex signaling pathways are related to this unique herbicide response.

Microbial Diversity in Response to Solarization. Tanner S. Hoffman*, Linda T.a. van Diepen, Andrew R. Kniss; University of Wyoming, Laramie, WY (048)

Soil solarization is a pest control treatment in which a clear tarp is laid over a fallow field targeting pests through passive solar heating. While region-specific effectiveness has been documented in peer reviewed papers, little is known of non-target effects on potentially beneficial microorganisms. A field study to determine how microbial diversity responds to varying degrees of solarization was conducted in the summer of 2020 in Laramie, Wyoming. Three treatments were included: no solarization (control), 3 weeks of solarization, and 6 weeks of solarization. Treatments were arranged in a randomized complete block design with 4 replicates. Three soil samples were taken from each replicate and homogenized prior to laying the plastic, and again when the plastic was removed, with the control plot being sampled with each removal time. Samples were stored at -20 degrees C until DNA extractions took place and were then sent to the University of Colorado for Illumina-based sequencing. Due to unforeseen circumstances (PCR and sequencing supplies being redirected to covid-19 efforts) the genomic data has not yet been returned from the sequencing facility. Once data is returned, beta diversity will be measured between treatments using a permutation multivariate analysis of variance test (adonis) and visualized using a non-metric multidimensional scaling ordination plot. P-value > 0.05 will indicate no significant differences in community composition between treatments, while a p-value < 0.05 will indicate significant differences.

WESTERN AQUATIC PLANT MANAGEMENT SOCIETY: AQUATICS

The Phenology of Flowering Rush (*Butomus umbellatus*) in the Western United States. John D. Madsen*[1], Kurt D. Getsinger[2]; [1]USDA-ARS, Davis, CA, [2]US Army Engineer Research and Development Center, Vicksburg, MS (063)

Flowering rush (*Butomus umbellatus*) is an invasive aquatic plant with western infestations in Montana, Idaho, and Washington. We are examining the phenology of this species in two separate studies. In the first study, we established plants from populations in western Montana, eastern Idaho, and northwestern Minnesota in a common garden area at the Davis, CA research facility to compare seasonal growth of separate populations in a common environment. Plant height and phenological characteristics were measured weekly, and biomass samples were collected monthly from each population for a two year period. No growth differences between populations were detected. Shoot growth was initiated in March, and senescence began in September. Rhizome bud formation began in June, and ceases in September. In the second study, we collect biomass samples from three locations (Idaho panhandle, western Montana, and eastern Idaho) four times a year (spring, early summer, late summer, fall) for two years. Bud densities range from 500 to 1200 rhizome buds per square meter, which translates to between 2 and 5 million buds per acre. Growth was evident from June through August. The results of this study are consistent with those of a phenology study on Detroit Lake, Minnesota. The goal of long-term management, at least for triploid flowering rush, should be to prevent rhizome bud formation and deplete the rhizome bud bank.

Sequential Years Spraying to Reduce Flowering Rush Rhizomes. Peter M. Rice*[1], Virgil Dupuis[2], Ian McRyhew[2], Alvin Mitchel[2]; [1]Peter M Rice Consulting, Missoula, MT, [2]Salish Kootenai College, Pablo, MT (064)

Flathead Lake is at low pool drawdown in late winter through May. This seasonal drawdown regimen provides a dry ground treatment window for soil active herbicide uptake via roots. Two herbicides: Clearcast at 841 g ae/ha or 1,121 g ae/ha depending on the year and Habitat 1,681 g ae/ha, both with 2 qt/ac MSO, were applied as "dry ground" treatments in May. Treatments were repeated for seven years (2014-2020). The long-term goal was to reduce the regrowth potential from the rhizomes. After six years Clearcast plots still had 46,538 rhizome leaf initials per acre in early spring 2020 before the seventh spray treatments were made. This density of emergent leaf tips after the first six Clearcast treatments would be sufficient to reestablish a dense infestation in one summer regrowth season without re-spraying. Habitat was consistently more efficacious than Clearcast. Canopy cover control during first six summers after spring spraying Habitat ranged from 95 to 100%. This level of single summer-long top growth control from Habitat was commercially acceptable to lakeshore owners of small areas. Clearcast was less efficacious with summer topgrowth control ranging from 62 to 86% over the first six summers. In the summer of 2020 after the seven treatments 100% topgrowth control was finally obtained by both herbicides. Rhizome weights and density were also reduced by both herbicides. This long-term herbicide effort confirms the necessity of developing biocontrols for suppression of flowering rush economically for numerous small infestations and at watershed scale infestations.

Selection and Application of PRE/POST-Emergent Herbicides for Western Irrigation Systems: Environmental Impacts on Both Sides of the Equation. Andrew Skibo*; Alligare LLC, Missoula, MT (065)

Surveys were conducted in May and August over 2019 and 2020, in order to bracket the period of increased, seasonal operational discharges at Holter Dam, a facility operated by the US Bureau of Reclamation near Wolf Creek Montana. Passive hydroacoustic methodologies, utilizing multichannel SONAR frequencies, were coupled with more traditional point-intercept techniques to allow high-throughput mapping and digitization of an approximate 55 kilometers long research area. The resultant temporospatially-located data sets allowed for analysis throughout the entirety of the surveyed areas and across multiple seasons, 2019-2020. Subsequent statistical analysis allowed for the development of a baseline data set on submersed aquatic vegetation (SAV) species populations and relative densities; and served to document benthic sediment transport-deposition dynamics and fluvial geomorphology following controlled operational releases at the dam. Preliminary data suggests that the impact of seasonal discharge at volumes measured in 2020 (~11,500 cubic feet per second, cfs) to established, deeply rooted submersed aquatic vegetation populations may be limited to within the first few miles of the river downstream from Holter Dam. Fluvial transport of fine, benthic sediments (silt) was noted throughout the upper study area, upstream of several confluences of tributaries to the Upper Missouri River, and several depositional locations were noted to have been colonized by SAV species the following season. These surveys suggests that while typical spring discharge regimes can transport fine benthic substrates conducive to SAV colonization and growth, peak flows in excess of 11,000cfs are needed to adequately scour established SAV populations from extant sites within this localized river system. Within the context of hydrodynamic processes that may interact with SAV population densities within the Upper Missouri River, little is known currently. The implications of high flow scouring of coarse gravels and their subsequent deposition within this study range appear to have far greater effect than was previously known and may offer a model of upstream river management in an effort to reduce the pressures of nuisance SAV species. The implications of combining traditional survey techniques with next generation hydroacoustic technologies suggest large-scale hydrodynamic and hydrobiological assessments may be conducted anywhere and allow for near real-time digitization of surveyed waterways.

IPM In Aquatic, Natural Areas and Rights of Way. Lyn Gettys*; UF/IFAS Ft. Lauderdale Research and Education Center, Davie, FL (066)

This presentation will focus on IPM (integrated pest management), the strategy of using "all the tools in the toolbox" to control invasive species. Dr. Gettys will outline the philosophy of IPM and discuss the four main types of management strategies that can be used in IPM programs in aquatics. She will also cover detailed case studies that highlight the benefits of using an integrated approach and will provide examples of how IPM is being used for control of a number of invasive aquatic plant species.

Endothall Development and Stewardship in Irrigation Canals. Nathan Hicks*; UPL, Dixon, CA (067)

Endothall was first used for aquatic plant management in 1960 and registered for use in irrigation canals in 2009. Endothall has a short aquatic half-life of two to fourteen days and breaks down into the organic acids (acetic and maleic). Two formulation of endothall are registered for use in irrigation conveyances. Cascade® is a formulated as a dipotassium sale and targeted at vascular plant control while Teton® is an amine salt formulation that controls both vascular plants and algae. Endothall is now listed a group 31 herbicide known to inhibit product of serine threonine protein phosphatase in cellular metabolism. Recent research indicates that endothall has systemic activity in some key weeds challenging the idea that it has only contact activity. Endothall's unique mode of action and its systemic activity should help water managers plan to prevent or manage weed resistance in irrigation canals. Additionally, recent research indicates some difficult weeds (Horned Pondweed) may be controlled using the highest labeled application rate with a short exposure time of forty minutes. Even though endothall is an older molecule, new uses and use patterns continue to be discovered.

California's Hydrilla Eradication Program: Challenges, Successes, and Future Directions. Robert A. James*; California Department of Food and Agriculture, Sacramento, CA (068)

Paper withdrawn

Soft Sediment Reduction Using MD Pellets and MuckBiotics. Deborah L. Lee*; Aquafix Inc., Madison, WI (069)

Over time, many ponds and lakes will experience a build-up of soft organic sediments (muck). The accumulation of muck depth leads to problems such as high algal or aquatic plant growth and decreased water volume. Muck accumulated in water resources can be difficult to remove and often leads to the release of nutrients such as inorganic phosphorus and nitrogen. High levels of phosphorus in a water resource are known to select for cyanobacterial blooms, which in some cases, may be detrimental to human health. There are a few products currently available to decrease the depth of muck in a water resource through biological means, however, the efficacy of these products has yet to be established. Naturalake Biosciences has developed an experimental laboratory setup and methods to test muck reduction. This lab setup and methods were used to assess the efficacy of Naturalake Biosciences' MD Pellets and MuckBiotics products to reduce pond muck. Fifteen-gallon standard aquarium tanks with added pond muck were used, with or without washed sand or clay layers, and with pond water over the muck to a specified height. The tanks also contained two submerged powerhead pumps to provide lateral water movement over the sediment. Measurements of muck depth and water quality were taken weekly. The lab tanks with added MD Pellets or MuckBiotics showed sediment reduction that was greater than that of the Control tanks. This lab setup may be more representative of the water movement over the sediments in a pond and may explain why typical bucket tests or tests with muck in 5-gallon aquariums without pumps do not give satisfactory results. In our experiments with MD Pellets or MuckBiotics, we observed nutrient levels reduction with decreases in sediment depth. We also observed differences in the microbial community in the tanks treated with MD Pellets or MuckBiotics compared to the Control tanks. The Naturalake Biosciences lab setup and methods for assessing biological reduction of pond muck appeared to be more accurate than previous methods for assessing the efficacy of biological muck reducing products.

Estimating *Lyngbya wollei* Biomass Using Non-Destructive Echosounding Measures. Andrew Howell*; North Carolina State University, Raleigh, NC (070)

Mat-forming populations of *Lyngbya wollei* (lyngbya), a nuisance cyanobacteria, continue to gain recognition among southeastern U.S. waterways due to rapid biomass development, increasing spatial abundance, and mysterious temporal trends. Waterbodies claiming lyngbya presence often report negative impacts on recreation, property, and native macrophyte growth. While factors of lyngbya presence and abundance have been studied, researchers still seek to identify the unique biological, chemical, and physiological processes which promote lyngbya progression, and thus successful management. Detecting and quantifying lyngbya has proven challenging for studying, as populations may be found stratified throughout the water column. Further, potentially deleterious populations may go undetected until surface mats emerge, and benthic or other subsurface populations are difficult to measure using traditional rake-toss survey strategies. Several echosounding techniques have successfully quantified submersed vascular species for decades, though none have documented the ability to identify and quantify cyanobacteria populations over time. However, preliminary research results from 2018 suggest the ability to sense and provide a measure of lyngbya water column occupancy using a high frequency, scientific-grade echosounding unit (Biosonics MX). Current research efforts are being conducted at Lake Gaston, North Carolina to develop a method which would allow quantifying lyngbya abundance using non-destructive biomass estimates and provide a repeatable, timely survey option for management.

The Aquatic Plant Management Society Update. John D. Madsen*; USDA-ARS, Davis, CA (095)

This will be an update on the state of the AMPS as a whole and the current state of the society and direction.

Aquatic Ecosystem Restoration Foundation Update. Carlton Layne*; Aquatic Ecosystem Restoration Foundation, Marietta, GA (096)

Will cover AERF's social media campaign and update attendees on the new EPA/CoE Waters of the United States rule and its likely effect on aquatic plant management activities.

Women of Aquatics Update. Sonja Wixom*; Pond Medics, Prosper, TX (097)

Abstract not available

The First Year of Operational Use of Florpyrauxifen-benzy Herbicide in the Pacific Northwest, Observations and Results. Terry McNabb*; Aquatechnex, LLC, Bellingham, WA (098)

In February of 2018, the US EPA registered ProcellaCOR as a new aquatic herbicide for a number of invasive aquatic weed species. This herbicide received a reduced risk classification from EPA and has one of the fastest plant accumulation factors known, meaning it has applications in high water exchange environments where contact exposure times are low. While we were able to get into the field in 2018 in some limited cases, states like Washington had to amend their NPDES permit to allow for the use of this new technology and treatments could not occur until July 5th of 2019. Aquatechnex biologists applied ProcellaCOR to approximately 1,000 acres throughout Washington, Idaho and Montana in the summer of 2019 and were able to follow up on these treatments to document results. This paper will present a number of treatment scenarios, use rates and application techniques and note results against Eurasian and Hybrid Milfoils and Parrotsfeather infestations.

Chemical-Free Algae Mitigation with Air Nanobubbles. Christian Ference*; Moleaer Aeration, Torrance, CA (099)

The use of air nanobubbles to mitigate and manage algae in surface waterbodies is a promising, new area of research that provides a novel, chemical-free solution to waterbody management. The neutral buoyancy, efficient gas transfer, and oxidative impact of nanobubbles has led to the successful management of algae in numerous waterbodies where traditional aeration and chemical treatments have failed. This presentation will include a review of several successful air nanobubble installations on lakes up to 25 acres as well as an in-depth case study where air nanobubbles were used to treat cyanobacteria in water collected from Lake Elsinore, CA. Lake Elsinore has been historically vulnerable to algae blooms and routinely issues recreational advisories due to dangerous levels of cyanotoxins. In this test, algae and toxin samples collected from a drum of Lake Elsinore water circulated with air nanobubbles was compared to samples collected from a drum of Lake Elsinore water circulated without nanobubbles. Data from this test shows that within 4 hours, the control drum experienced a 7.5% increase in cyanobacteria and a 31.5% increase in microcystin while the drum that received nanobubbles indicated 40% reduction of cyanobacteria with a minimal increase in microcystin. Based on these results and more than 200 field observations, the latest understanding of nanobubble treatment of algae is that nanobubbles provide a multifaceted solution to algae treatment. Upon introduction of air nanobubbles, immediate reduction of algae occurs through oxidation and long-term algae mitigation is achieved through enhanced aeration and reduced sediment nutrient cycling.

The Role of the Southwestern Aquatic Applicator. Rick Amalfi*; Aquatic Consulting, Tempe, AZ (100)

The southwestern United States presents unique challenges to the aquatic applicator. Varied environments, waters, and public perceptions have a direct impact on the success of target species/organism control. An integrated treatment approach must be used by applicators to address these conditions to ensure treatment success. Case studies will be used to demonstrate how the unique environment of the desert southwest can present challenges.

Endothall Translocation in Three *Hydrocharitaceae* Species. Mirella F. Ortiz*, Scott J. Nissen; Colorado State University, Fort Collins, CO (101)

Eelgrass (*Vallisneria americana*), hydrilla (*Hydrilla verticillata*), and Brazilian elodea (*Egeria densa*) belong to the*Hydrocharitaceae* family. Members of this plant family are both important component of aquatic ecosystems and problematic aquatic weeds. Eelgrass is an important native plant species providing food and wildlife habitat for fish and improving water quality and clarity, while hydrilla and Brazilian elodea are problematic invasive species. While these aquatic plants belong to the same family they respond very differently to the aquatic herbicide, endothall dipotassium salt (Aquathol K). Although endothall was considered a contact herbicide, recent studies have shown that it has systemic activity. The goals of this research were to determine if endothall absorption and/or translocation from shoots to roots could explain why these plants respond differently to endothall. Hydrilla and egeria were clonally propagated from apical shoot cutting, while vallisneria was propagated from runners. For herbicide absorption and translocation, plants of each species with developed roots and approximately 15 cm of shoot growth were transferred to test tubes and sealed at the top with a low melting point eicosane wax to isolate the root system from the water column. Plants were exposed to 1 ppm formulated endothall plus radiolabelled herbicide over a 192 hour time course. All three species had linear increases in endothall absorption, never reaching a maximum asymptote. Based on the plant concentration factor (PCF), vallisneria concentrated significantly more herbicide compared to hydrilla and egeria; however, translocation to vallisneria roots was significantly less. Over the 192 hour time course the maximum translocation to vallisneria roots was only 6% compared to

25% of the total absorbed radioactivity in egeria and hydrilla (both monoecious and dioecious). These data provide additional evidence that endothall behaves as a systemic herbicide but does not provide conclusive evidence for the mechanism of selectivity, but there could be differences in endothall metabolism resulting in limited translocation in vallisneria.

Why Herbicides Fail. Jay Ferrel*; UF/IFAS Center for Aquatic and Invasive Plants and the Pesticide Information Office, Gainesville, FL (102)

This presentation will focus on some of the reasons that herbicide applications may have reduced efficacy or may fail altogether. Topics will include environmental conditions, timing and herbicide choice.

Evaluation of Unmanned Aerial Vehicles for Weed Mapping and Site Specific Weed Management. Andrew Howell*; North Carolina State University, Sanford, NC (103)

Unmanned aerial vehicles (UAVs) have been used in agriculture to collect imagery for crop and pest monitoring and for decision-making purposes. Spraying-capable UAVs are now commercially available worldwide for agricultural applications. Combining UAV weed mapping and UAV sprayers into an UAV integrated system (UAV- IS) can offer a new alternative to implement site-specific pest management. The UAV-IS was 0.3- to 3-fold more efficient at identifying and treating target weedy areas, while minimizing treatment on non-weedy areas than ground-based broadcast applications. The UAV-IS treated 20–60% less area than ground-based broadcast applications, but also missed up to 26% of the target weedy area, while broadcast applications covered almost the entire experimental area and only missed 2–3% of the target weeds. The efficiency of UAV-IS management practices increased as weed spatial aggregation increased (patchiness). Integrating UAV imagery for pest mapping and UAV sprayers can provide a new strategy for integrated pest management programs to improve efficiency and efficacy while reducing the amount of pesticide being applied. The UAV-IS has the potential to improve the detection and control of weed escapes to reduce/delay herbicide resistance evolution.

From Bench Scale Trials to Field Cyanobacterial Management with PAA+ Peroxide. Tom Warmuth*; BioSafe Systems, East Hartford, CT (104)

Development of effective treatments for cyanobacterial management are emerging as a needed option as the threat to our water resources by these organisms becomes more realized and understood. The need for tools to cyanobacteria known to produce harmful toxins and taste and odor compounds is an important ongoing focus in the field of surface water management. Bench Scale trials at Clemson University on bloom level densities of the cyanobacteria Microcystis aeruginosa (1.9 million cells/ml) lead to effective field application rates in full-scale surface treatments of municipal potable water sources. A few different sites and their treatment results will be discussed as case studies, application methods, and results utilizing a liquid PAA + Peroxide formulation. Peroxide-based algaecides have been identified as effective in selective treatments for cyanobacteria, where it is not greatly affecting non-target organisms, zooplankton, beneficial green algae and other phytoplankton. This all leading to a better water body or potable water source through more targeted treatment and control.

Preventative Submersed Aquatic Weed Control Utilizing a Preemergence Use Pattern of Fluridone. Scott Shuler, Michael Shaner, Ajay Jones*, Mark Heilman; SePRO Corporation, Carmel, IN (105)

Fluridone research has been conducted on preemergence use patterns in terrestrial environments since the late 1970s. Typical small-waterbody management for submersed aquatic weeds has utilized contact herbicide applications as a reactive management approach to nuisance conditions. This management strategy may require increased labor, has risks associated with dissolved oxygen depletion and nutrient release from decaying vegetation that may exacerbate nuisance algal growth. ECOS® is a preemergence use pattern utilizing SonarOne® Aquatic Herbicide to provide preventative submersed aquatic weed control. Over 3,500 ponds managed under the ECOS Program were evaluated for efficacy, spectrum of control, length of control, herbicide and algaecide inputs and operational efficiency during a two-year period. Season-long, broad-spectrum submersed weed control was achieved on 77-99% of the ponds depending on geography, plant community and timing of initial application. Algaecide inputs were reduced on the ECOS ponds by 17-35% depending on the year and region of the country. Evaluation of the 3,500 ECOS ponds shows this preemergence program provides effective broad-spectrum, seasonlong control of submersed aquatic weeds and reduced labor and algaecide inputs.

What to Look for in Water Quality When Managing and Learning About Ecosystem-Specific Algal Blooms. Sam Sardes*; SOLitude Lake Management, Tampa, FL (106)

In today's changing aquatic climate, it is not enough to just show up at water bodies and treat the nuisance algae with algaecides. Lakes that are chosen for restoration may require one or more of a wide variety of IPM tools. Water quality of a lake can greatly impact which types of algal blooms may occur and which restoration tools will be the most appropriate. This presentation reviews the different water quality parameters that are important to examining algae blooms. For example, benthic mat forming *Scytonema* sp. thrive in lakes with high alkalinity and alkali bottoms like limestone. Another example is analyzing the total nitrogen to total phosphorus ratio to help predict whether a planktonic algae bloom will be predominantly cyanobacteria. These are just a few of the many ways water quality data can be used to examine algae blooms and help determine which restoration tools are most appropriate to the specific ecosystem.

Do Cyanbacteria Spill Their Guts When Treated with an Algaecide? John H. Rodgers*; Clemson University, Clemson, SC (107)

The 'leaky cell hypothesis" was founded on the premise that application of algaecides to control toxin producing cyanobacteria causes leakage of endotoxins (e.g., microcystins) and leakage increases ecological and human health risks. Data from algaecide applications in the field have failed to support this hypothesis. In this presentation, the original data used to support this hypothesis are examined, and recent data are presented that evaluate the validity and utility of this hypothesis for decision making. The leaky cell hypothesis is not generally applicable, and the concept is very limited in terms of applicability to algaecides used to treat dense populations of microcystin producers near drinking water intakes. Risk assessment indicates that intervention should have been initiated earlier and risk would not be avoided by not intervening.

The Threat of Cyanbacteria and Cyanotoxins. West Bishop*; SePRO Corporation, Carmel, IN (108)

Cyanobacterial blooms are increasing in duration and intensity in all regions of the United States. Toxic cyanobacteria pose significant risks to the ecological system and human health due to the potential production of numerous types of toxins (e.g. neurotoxins, hepatotoxins, dermatoxins). Humans and wildlife associated with the water are exposed to these toxins in many ways such food chain accumulation, water supply, aerosolization and recreational activities. Acknowledging the multiple toxins, both currently described and yet to be characterized, numerous exposure routes, and potential for significant impacts; direct management is critical if toxins are present. Often there are concerns over applying USEPA approved algaecides to these blooms due to the release (or potential) of these toxins. Even though many toxins are already found in the dissolved state, will be innately released, and total toxin increases exposure potential, applied management is still restricted. Novel management approaches are needed to address these concerns and restore the uses of the water resource. The objectives of this presentation are to cover some approaches for mitigating toxic cyanobacterial blooms both proactively and reactively as well as address the toxins.

Effect of Herbicides on Sprouting Curlyleaf Pondweed Turions. Lars Anderson*; Waterweed Solutions, Inverness, CA (109)

Curlyleaf pondweed (*Potamogeton crispus*) was first identified in the Tahoe Keys in the 2003/2004 growing seasons, within the channels that connect the Keys to Lake Tahoe proper. Subsequently, *P. crispus* has spread throughout the Keys as well as areas along the south nearshore areas of Lake Tahoe. Management of SAV (e.g., *Ceratophyllum demersum* and *Myriophyllum spicatum*) in the Keys has been primarily by mechanical harvesting which generates viable propagules, including turions, that have contributed to expansion of curlyleaf pondweed populations in Lake Tahoe. This study was done to determine the effects of endothall (potassium salt), penoxsulam, and florpyrauxifen-benzyl on newly sprouted turions. If efficacy is sufficient, then late summer/early fall applications may be useful in reducing the spread of curlyleaf pondweed. This timing could also reduce the total amount of herbicide required since water levels are typically lowest at in fall. Results show that turions that had sprouted for 5 to 10 days were either killed by one- time, 7-day exposure to 2.0 ppm endothall, or exhibited >95% reduction in leaf production. Exposure to florpyrauxifen-benzyl at 2.0 ppb produced stunted shoot growth and >90% leaf production. Two treatments of Penoxsulam at 20 ppb resulted in stunted plants and 60% reduction in leaf production. Although spring applications of herbicides should be effective in controlling established curlyleaf pondweed, fall applications may provide significant beneficial control by impairing the overwintering capacities of sprouted turions. These data suggest that a fall application of potassium salt of endothall or florpyrauxifen-benzyl, both of which have short half-lives, may be an effective component of an integrated strategy to control curlyleaf pondweed in the Keys and thereby significantly reduce risks of further infestations in Lake Tahoe proper. Currently, any use of aquatic herbicides in Lake Tahoe, or the Keys is still prohibited even though an application for small scale field demonstration in the Keys of endothall, triclopyr, and florpyrauxifen-benzil (for *M. spicatum* control) has been under review by regulatory agencies for three years. The 2020 growing and “boating season” will be the fourth year that Tahoe Basin regulatory agencies have effectively enabled the continued expansion of curlyleaf pondweed in the Keys and in Lake Tahoe in spite of available and proven and safe technologies that can control this and other invasive aquatic weeds in the Keys.

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

Indaziflam Injury to Root Systems of Non-target Perennial Grasses. Peter M. Rice*; Peter M Rice Consulting, Missoula, MT (071)

Two investigators in the Northern Rockies have been observing unanticipated root injury to perennial bunchgrasses after spraying Esplanade/Rejuvra for control of weedy winter annual grasses. Earlier indaziflam trials in the central Rockies did not report injury to in-situ perennial grasses. Trials in Montana have revealed that the root systems of northern montane cool season native perennial bunchgrasses are responding to indaziflam by root stunting and crown girdling. The diminished root systems make bunches susceptible to being pulled out of the ground by large ungulates. On one replicated test site elk pulled out 182,109 bunches per acre in the first growing season after the previous years late summer application of 103 g ai/ha. An example data set from another replicated test site where manual pull tests have been conducted had pull rates in the first growing season post-spray of 14.2% for no-spray controls, 27.5% at 40 g ai/ha, 37.5% at 73 g ai/ha, and 44.2% at 103 g ai/ha. There was recovery at the lower rates in the second growing season post-spray when pull rates were 14.2% for no-spray controls, 10.0% at 40 g ai/ha, 28.3% at 73 g ai/ha, and 46.7% at 103 g ai/ha. This investigator quantified root injury on five replicated trial sites from western to south central Montana; and observed root injury and large ungulate pull out on numerous other sites. All the native bunchgrass species present on these sites were susceptible: Idaho fescue, bluebunch wheatgrass, slender wheatgrass, needle and threadgrass, Sandberg bluegrass, and other *Poa* spp.

Restoring Cheatgrass Invaded Rangelands with Indaziflam Decreases Wildfire Risk and Improves Wildlife Browse and Habitat. James Sebastian*[1], Shannon Clark[2], Derek J. Sebastian[2], Steve Sauer1; [1]Boulder County Open Space, Longmont, CO, [2]Bayer CropScience, Fort Collins, CO (072)

Boulder County Open Space (BCOS) manages properties in the lowland, foothills and mountains of Colorado that provide critical overwintering habitat for mule deer, elk, and other wildlife. A major concern of BCOS ecologists and wildlife biologists is the loss of critical wildlife habitat areas due to cheatgrass-fueled wildfires. In winter 2017 and 2018, six sites were treated with Rejuvra® (indaziflam, Bayer) (7 oz/ac) plus glyphosate (12 oz/ac), while desirable shrub species were in dormancy and no leaves were present. These sites were 2 to 20 acres in size with dense stands of mountain mahogany, four-lobed sumac, antelope bitterbrush, winterfat, rubber rabbitbrush, four-winged saltbush, and fringed sage. Permanent random transects (3 X 200') were created inside cheatgrass-treated, and immediately adjacent, non-treated plots. Data collection included line intercept canopy cover for cheatgrass and all desirable perennial vegetation. In addition, biomass was collected for all species including cheatgrass litter to determine fine-fuel weights in treated vs. non-treated plots. This provided an indication of how quickly cheatgrass fine-fuel litter degrades after Rejuvra® treatments. Shrub measurements including longest leader growth were collected along the entirety of the transect. Data were collected over two consecutive summers, at approximately 8 and 20 months after treatment (MAT). The first summer after application, cheatgrass litter biomass averaged 935 lb/A in non-treated areas compared to 82 lb/A in treated areas, a 92% degradation of cheatgrass litter in areas treated with Rejuvra®. By the second summer after application, cheatgrass litter had completely degraded on Rejuvra® treated sites. Perennial grass at the sites responded positively to the treatments, with an average 5x increase in biomass by 20 MAT (Figure 1). New growth measurements on shrubs spanning the transect lines revealed increased leader growth and shrub canopy volume in the treated areas for all seven shrub species evaluated. New leader growth was 1.5x to 2.8x longer on shrubs in areas treated for cheatgrass compared to non-treated areas (Figure 2), while shrub canopy volume increased 120% to 400% with cheatgrass treatments (data not shown). Our research has shown that mule deer browse and forb forage dramatically increased where cheatgrass is controlled. To further quantify mule deer visitation and utilization, additional data collection techniques were implemented. These included game cameras, exclosures, and track and pellet counts. Game cameras were set up at 3 of these same 5 sites in November 2020 to monitor mule deer presence and duration of activity inside treated and immediately adjacent non-treated areas. Number of photos, deer numbers, deer/photo, and % daily use were recorded daily. Mule deer track (in snow) and pellet count data were collected along the same 200' transects to support game camera data. Paired 10' x 10' exclosures were also set up at these 3 sites to monitor actual utilization with and without mule deer browsing. This data will be collected at the end of the 2021 growing season after browse and forbs have fully matured and again at the end of the 2022 winter after mule deer have intensely browsed the sites. This research suggests that Rejuvra® could be a useful tool in wildlife habitat improvement projects on invasive winter annual grass dominated sites. In this study, wildlife browse was increased for seven different shrub species utilized by mule deer, elk and other browse species during winter months, indicating a substantial improvement to critical winter range in Boulder County, CO. Our findings reinforce the findings of field managers, that cheatgrass and other invasive annual grasses pose a significant threat to the habitat and population of browse species. For land managers, this management tool provides a long-term control option to reduce wildfire risk and begin the restoration process on the millions of infested acres within critical habitat areas.

Four Years After Application: Medusahead Control with Indaziflam in North Eastern California. Thomas J. Getts*; University of California Division of Agriculture and Natural Resources, Susanville, CA (073)

Medusahead (*Taeniatherum caput-medusae L.*) is an invasive winter annual grass listed as noxious in six western states due to its ability to create monocultures displacing desirable vegetation. Indaziflam has been shown to offer long term control of other winter annual grasses such as cheatgrass. This research tested long term control of medusahead with indaziflam in the Intermountain Region of California. In March of 2016, four replications of herbicide treatments were made to 3*12m plots in a randomized complete block design at two sites (Goose Lake and Adin). Eight desirable perennial grasses were drill-seeded in the spring of 2017 and again in the spring of 2018 to test potential for grass establishment in treated areas. An additional trial was implemented in November of 2016 to investigate medusahead control with indaziflam shortly after germination on a rocky site where no seeding was planned. Studies were monitored in 2017, 2018, 2019, and 2020 to assess medusahead control visually. Perennial grass establishment was assessed at the spring sites in 2019 by harvesting above ground biomass in 0.5 m^2 quadrats separating by species class and drying in a 50 deg C oven for 24 hours. Medusahead control was excellent with indaziflam in 2017 and 2018 at all sites. This paper will focus on results for the 2019 and 2020 evaluations. At the Adin site, indaziflam at 72 and 102g ai/ha provided 57% and 52% medusahead control 39 months after treatment (MAT), and 22% and 26% control 52 MAT. At the Goose Lake site, indaziflam at 72 and 102g ai/ha provided 72% and 70% medusahead control 38 MAT, and 57% and 57% medusahead control 51 MAT. Perennial grass establishment was poor for all seeded species, except intermediate wheatgrass, which only established where medusahead was suppressed by indaziflam. Because of sporadic establishment of the other species, biomass was only harvested in the intermediate wheatgrass seeding. In the 72 g ai/ha indaziflam treatment, there was 120g/m and 160g/m of dry intermediate wheatgrass biomass compared to 0g/m and 15 g/m in the untreated control at the Adin and Goose Lake sites respectively. In the fall study, treatments of indaziflam at 72 and 102g ai/ha resulted in 94% and 87% medusahead control 31 MAT, and 80% and 27% control 43 MAT. Results from these three trials showed that medusahead control three and four growing seasons after application was variable across sites. Two of the three sites provided adequate medusahead suppression three years after treatment, but in the fourth year after application, most of the treatments had broken. However, in the fourth year after treatment, control was variable between replications of indaziflam treatment. Some replications of indaziflam showed no annual grass control, and other replications still provided adequate control. In the spring studies, intermediate wheatgrass only established where medusahead was suppressed by applications of indaziflam, with little to no establishment in the untreated checks. Results from the seeding study indicate it is possible to successfully establish intermediate wheatgrass in areas where indaziflam has been applied to suppress medusahead.

Spring Application of Aminopyralid Reduced Germination of Medusahead and Ventenata.
Lisa C. Jones*[1], Corey V. Ransom[2], Timothy S. Prather[1]; [1]University of Idaho, Moscow, ID, [2]Utah State University, Logan, UT (074)

Prior research shows that aminopyralid has activity to (1) control medusahead when applied preemergent or early post emergent in the fall and (2) decrease viability of medusahead seed when applied at the boot stage. We conducted studies in Idaho and Utah from 2017 to 2019 of seven aminopyralid treatments plus an untreated check, applied in winter, spring, and fall. We tested if sequential pre- and post-emergent applications resulted in multi-year control of medusahead and decreased germination rates. In the first growing season, plots treated with the low (0.092 lb ae/A) and high (0.184 lb ae/A) rates of aminopyralid in fall then spring, and the single fall treatment at the low rate had the best control (92-100%). After the first season, seeds from areas treated with aminopyralid at both rates in fall then spring, spring then fall, and the single application of the low rate in spring had the lowest germination rates (0-25%). Where the initial spring 2018 application did not control medusahead the first year, germination from those plots was substantially reduced, resulting in improved control in 2019 after a second herbicide application. In the second growing season, plots treated with aminopyralid in the fall then spring at both rates, spring then fall at both rates, and sequential fall or spring applications had the best control (76-100%). Germination rates from seeds collected in 2019 were lowest for the sequential spring applications (13-53%). While no treatment controlled ventenata in Idaho, the 2019 germination rate was 0% for seeds treated with the sequential spring applications.

Noxious, Invasive and Non-Crop Weed Control with Florpyrauxifen-benzyl + Aminopyralid: Western Species Research Update. William L. Hatler*[1], Byron B. Sleugh[2], Scott Flynn[3], D Chad Cummings[4]; [1]Corteva Agriscience, Meridian, ID, [2]Corteva Agriscience, Carmel, IN, [3]Corteva Agriscience, Lees Summit, MO, [4]Corteva Agriscience, Bonham, TX (075)

Florpyrauxifen-benzyl + Aminopyralid are the components of two new herbicides (DuraCor® and TerraVue®) developed by Corteva Agriscience for control of broadleaf weeds and certain woody plants in rangeland, pastures, CRP, wildlife management areas, non-crop areas and other sites. These herbicides provide innovative new tools that are non-ester, non 2,4-D containing, low odor, low use rate formulations with postemergence and preemergence activity on susceptible broadleaf plants and seedlings, and some woody plants. They will provide control of all species controlled by GrazonNext® and Milestone® herbicides, plus many additional species and offer flexibility in application (ground, aerial, broadcast, or spot treatment). A key component of these products is florpyrauxifen-benzyl (Rinskor® active), a novel new active ingredient in range, pasture and land management, and an EPA Reduced Risk Pesticide. In trials over multiple years across the United States, excellent control has been seen on weeds such as Canada thistle (*Cirsium arvense*), wild carrot (*Daucus carota),* common caraway (*Carum carvi*), curly dock (*Rumex crispus*), buckhorn plantain (*Plantago lanceolata*), common mullein (*Verbascum thapsus*), Russian olive (*Elaeagnus angustifolia*), Scotch broom (*Cytisus scoparius*), and many more. Based on these efficacy data, these new herbicides will be valuable new tools in noxious, invasive and non-crop weed management in the western U.S.

Removal of Invasive Scotch Broom Imparts Negative Legacy Effects to Soil and Plant Communities. Robert Slesak*, Timothy B. Harrington; USDA Forest Service - PNW Research Station, Olympia, WA (076)

Scotch broom is an aggressive invasive species of major concern in coast Douglas-fir forests of the Pacific Northwest USA. Control efforts are common, but potential for ecosystem recovery following Scotch broom removal is unclear. We assessed the potential for ecosystem recovery following broom removal at two sites that contrasted strongly in soil quality in western Washington and Oregon. Comparison were made among replicated plots where Scotch broom was 1) kept out (never present), retained, or removed. Microclimate (PAR, soil temperature and moisture), soil properties, and vegetation were monitored over a period four years. Scotch broom removal increased PAR and soil temperature at both sites but had limited effects on soil moisture. Concentrations of soil Ca, Mg, K, and P were significantly lower with Scotch broom removal compared to the kept out and retained treatments, with the effect most pronounced at the low-quality site. NMS ordinations indicated that the treatments were distinctly different in vegetation composition, with no evidence for recovery in the removal treatment. Non-native exotic species and native species covaried in their response, where exotic species abundance was greatest in the removal treatment, intermediate in the retained treatment, and lowest in the kept out treatment, indicating occurrence of a secondary invasion following removal. As with the soil response, effects were more pronounced at the low-quality site. Our findings indicate that Scotch broom removal exacerbates negative effects on soil and plant communities, with no evidence of ecosystem recovery over our study period. Management actions should focus on controlling Scotch broom invasions immediately after establishment, especially at low-quality sites that are more susceptible to broom invasion and negative ecological legacies.

Evaluating Reclamation Methods of Rangeland from Invasive Annual Grasses. Cody J. Beckley*, Hailey L. Buell, Corey V. Ransom; Utah State University, Logan, UT (077)

Invasive annual grasses are an ever-present threat to the rangeland ecosystems of Utah and surrounding states. Previous studies on brome grass (*Bromus spp*.), medusahead (*Taeniatherum caput-medusae*) and Ventenata (*Ventenata dubia*) have demonstrated their ability to invade rangeland and dominate indigenous vegetation. Although effective herbicides and management practices have been developed for annual grass control, complete rangeland reclamation and restoration from invasive annual grass remains a serious challenge. Separate field studies were conducted in Utah rangeland settings from 2015 to present to evaluate herbicide control effectiveness and re-vegetation methodology. Sites were selected based on existing infestation of brome grass (Cherry Peak), medusahead (Paradise and Peterson), and Ventenata (Mt. Sterling). At Cherry Peak, all treatments reduced downy brome cover and with the addition of indaziflam, cover was reduced by 98.5 to 100%. Cover of Hooker's balsamroot, a native perennial, was not altered by any treatment whereas cover of Western wheatgrass was significantly reduced in plots treated with glyphosate alone, glyphosate with indaziflam, and imazapic with indaziflam. At Paradise native perennial grass cover was greater than 50% for all treatments at trial initiation. Medusahead cover was initially decreased by all herbicide treatments and further decreased for all treatments by a lack of grazing and declining weed cover after 2019 (<4%). At Peterson Western wheatgrass cover was less than 50% for all treatments at trial initiation. Medusahead cover was significantly reduced (=6%) by all Indaziflam and Indaziflam tank mixes over the life of the trial. Only two indaziflam tank mix treatments had significantly greater total crop cover (53%) than untreated (26%) in 2019. At Mt. Sterling, all treatments initially reduced medusahead cover however only treatments containing indaziflam were effective across multiple years. Species richness only increased with treatments providing more than one year of control. These studies suggest that indaziflam can be an effective tool for controlling invasive annual grasses for multiple years, but other factors will also significantly impact the ability of a site to be recovered from annual grass infestation and restored to native species.

Abiotic and Biotic Factors Associated with *Ventenata dubia* in Montana. Jane Mangold*, Michelle L. Majeski; Montana State University, Bozeman, MT (078)

Ventenata dubia has expanded rapidly across the Intermountain West, including Montana, in the last decade. Impacts associated with *V. dubia* include decreased biodiversity and forage production and increased soil erosion. Our objective was to explore abiotic and biotic factors associated with populations of *V. dubia* in Montana with the aim of identifying areas vulnerable to future invasion. At five sites we established 4, 50 m transects and estimated canopy cover of *V. dubia* and plant functional groups in 5, 0.1 m^2 frames placed 10 m apart. We also collected soil (553 cm^3 per frame, composited for each transect) and analyzed it for chemical and physical properties. Correlations between *V. dubia* cover and soil characteristics and vegetation were examined using mixed effects models. Potassium concentration was the only soil characteristic associated with *V. dubia* cover, and the association was negative; for every 1 part per million increase in potassium, *V. dubia* covered decreased by 0.05% (95% CI: -0.098 to 0.005). *Ventenata dubia* was negatively associated with bare ground and native perennial grass and positively associated with non-native perennial grass. For every 10% increase in bare ground or native perennial grass cover, *V. dubia* decreased by 1% (95% CI: -0.19 to 0.01) and 2% (95% CI: -0.30 to -0.04), respectively. For every 10% increase in non-native perennial grass cover, *V. dubia* cover increased by 2% (95% CI: -0.01 to 0.30). From our study we concluded the following implications for management: First, only a few of the factors we sampled were associated with *V. dubia*, and while our study was limited in scope, this could mean that *V. dubia* can invade sites with a wide range of conditions. Second, the distinction between nativity of perennial grasses and the type of association with *V. dubia*, with one being negative (native) and one being positive (non-native), suggests areas where native perennial grasses are decreasing or have been replaced by non-native perennial grasses should be prioritized for monitoring.

The Effectiveness of Traditional and Novel Management Strategies on Ventenata and Cheatgrass. Lilly L. Sencenbaugh*, Lisa J. Rew; Montana State University, Bozeman, MT (087)

Non-native annual grasses are invading western rangelands and novel approaches are needed to supplement existing weed management strategies. The aim of this study was to investigate biofumigation as a potential control strategy for two non-native annual grasses (downy brome, *Bromus tectorum* and ventenata, *Ventenata dubia*) and effects on native perennial grass species (bluebunch wheatgrass, *Pseudoroegneria spicata* and Idaho fescue, *Festuca idahoensis*). We tested the effect of the mustard biofumigant, *Brassica juncea*, applied as seed meal and dry mulch, to suppress germination of the four grass species in controlled environments. Seeds were placed in either non-soil or soil media, and exposed to increasing levels of seed meal or mulch, germination was recorded. In non-soil media, seeds that did not germinate were also tested for viability. The seed meal and mulch reduced germination of all species in both media. Non-native species had lower germination at the middle to higher concentrations of seed meal; bluebunch wheatgrass was the most tolerant and ventenata was the least. In the soil media, all species were impacted at the same levels for both seed meal and mulch. Further research in controlled and rangeland environments is required to confirm our preliminary results demonstrating the potential of mustard biofumigation to control non-native annual grasses.

Effects of Ventenata Control on Northern Mixed Prairie Ecosystem Goods and Services Two Years Posttreatment. Marshall Hart*[1], Brian Mealor[2]; [1]University of Wyoming, Sheridan, WY, [2]University of Wyoming, Laramie, WY (088)

Ecosystem goods and services are the benefits, tangible and intangible, that humans receive from ecosystems. While many intuit that invasive species removal will return benefits that were reduced by the invasive, this may not be true in all cases. In northeast Wyoming, ventenata (*Ventenata dubia Leers. Coss.*) has recently invaded Northern Mixed Prairie. Our objective was to evaluate the impacts of ventenata management on forage quality and quantity and plant species richness and diversity within a landscape-scale management program. We sampled plots where ventenata had invaded and was subsequently controlled, along with adjacent plots where ventenata was left unmanaged. We collected aboveground biomass by functional group in the two growing seasons following fall 2018 indaziflam treatment. In 2019, we sampled plots for biomass monthly throughout the growing season. COVID guidelines restricted biomass collection to July in 2020. We recorded canopy cover (%) by species in July of both years. Indaziflam reduced annual grass biomass ($p<0.01$), and increased perennial grass biomass ($p<0.05$). We observed no differences in total biomass or species richness or diversity. Perennial grasses were a higher quality forage than ventenata ($p<0.01$). Although the amount of nutrients present (kg ha^{-1}) did not change, differences in phenology and physical characteristics between perennial and annual grasses mean that perennial grasses provide a longer grazing window for cattle. These results have shed light on potential benefits of invasive species management, especially ventenata in the northern mixed prairie.

Priority Effects or Rapid Growth Rates: What Helps Cool-season Bunchgrasses Compete with Invasive Grasses. Jaycie N. Arndt*; University of Wyoming, Sheridan, WY (089)

Priority effects - the impact of early arrival of one species on later arrivals - and differential growth rates often distinguish the success of seedling grasses in semiarid rangelands. The phenology of small-statured native perennial bunchgrasses may allow them to compete with invasive annuals for temporal resources to grow rapidly and produce seed early. We investigated competitive interactions by comparing the effect of early emergence and growth rates on biomass production in two replicated greenhouse experiments using five invasive and four native perennials. We grew one individual of each species alone and in each native-invasive pairwise combination. We measured emergence and final biomass. We used ANOVA to determine differences in emergence, growth rate, and biomass between pooled native and invasive species and to investigate whether competitor identity affected biomass production of each species. In 2018 invasives emerged later ($p<.01$), grew faster, and produced more biomass ($p<.001$). In 2020 invasives emerged earlier, grew faster, and produced more biomass ($p<.001$). Prairie junegrass and ventenata were not decreased by competitors in 2018 ($p>0.05$) but were in 2020 ($p<0.001$). Downy brome, Japanese brome, medusahead, and bulbous bluegrass maintained biomass with competitors in 2018 and 2020 ($p>0.05$). Biomass of muttongrass, squirreltail, and spike trisetum were decreased by competitors in both years ($p<0.005$). Competition appears to be species dependent, but overall it appears that priority effects and growth rates do not help these cool-season bunchgrasses compete with invasive grasses.

Sagebrush Steppe Plant Community Response and Annual Grass Control After Aerial and Ground Application of Indaziflam and Imazapic. Georgia R. Harrison*[1], Lisa C. Jones[1], Harry Quicke[2], Timothy S. Prather[1]; [1]University of Idaho, Moscow, ID, [2]Bayer CropScience, Windsor, CO (090)

Invasive annual grasses continue to negatively impact sagebrush steppe by decreasing native plant diversity and shortening fire return intervals. An herbicide that has a long soil residual, such as indaziflam, can deplete invasive plant seedbanks while releasing remnant native plants from competition. Large areas can be efficiently treated using aircraft, but low application volume may result in lower control. We compared application types and rates on rangeland near Hailey, ID in sagebrush dominated plant communities. Within the same pasture, indaziflam alone or indaziflam plus imazapic (70 and 84 g/Ha active ingredient, respectively) were applied aerially at 23, 47, 96, and 187 L/Ha by airplane and helicopter and by ground at 96 and 187 L/Ha. Treated areas, including untreated swaths, encompassed 6.3 and 5.7 hectares for helicopter and airplane, respectively. Foliar cover was assessed pre- and post-treatment in 9 m^2 permanent quadrats within treated and untreated areas that represent surrounding plant communities. All herbicide applications controlled annual grass (*Bromus tectorum* and *B. japonicus*) foliar cover by 49 to 100% compared to plots without herbicide. Best control (>98%) was achieved with helicopter applied indaziflam + imazapic at 96 and 187 L/Ha, and ground applied indaziflam + imazapic at 96 L/Ha. Within airplane treated groups, the best control (94%) was achieved with indizaflam applied at 96, and 187 L/Ha. Perennial grass cover increased in airplane and ground treated plots. We present observations one year post-treatment, but will continue to monitor plots to assess long-term control and plant community response.

Does Seeding Depth Affect Native Species Establishment in the Presence of Indaziflam? Jodie A. Crose*[1], Brian Mealor[2]; [1]University of Wyoming, Sheridan, WY, [2]University of Wyoming, Laramie, WY (091)

Indaziflam was recently labeled for annual grass control in rangelands. Selectivity results from its soil binding properties, confining it to the top few centimeters of the soil profile. Its impacts on desirable species seedling recruitment is not well documented. Our objective was to evaluate how emergence is influenced by planting depth with and without indaziflam. We used a series of studies – two in the greenhouse and one under field conditions – to evaluate interactions between indaziflam and seeding depth on four desirable species. In the greenhouse, we planted seeds in rows at 2.5, 1.3, 0.6, and 0 cm depth in 5.7 L plastic containers with a 3:1 mixture of clay loam soil and potting medium. We sprayed twelve containers with indaziflam at 73 g ai ha^{-1} and left twelve untreated for each greenhouse trial. We recorded seedling emergence 48 days after planting (DAP). We carried out similar methods for a field trial where we evaluated plant density 34 DAP in indaziflam-sprayed and nonsprayed plots. Greenhouse results indicated that emergence varied by seeding depth and indaziflam for all species, but under field conditions plant density was nearly zero with indaziflam regardless of species or planting depth. Field emergence was similar to the greenhouse trials in nontreated plots. Indaziflam negatively affected emergence from species that require shallower planting depths more than those suited to deeper depths.

Considerations of Life Cycle in Invasive Mustard Management. Natalie L. Fronk*, Corey V. Ransom; Utah State University, Logan, UT (092)

Consideration of life stages is critical in invasive mustard management and research. To explore management options for mustards of diverse life cycle patterns, plots were established in infestations of dyer's woad (biennial), elongated mustard (biennial or simple perennial) and African mustard (winter annual) in Utah. A variety of herbicide treatments were applied to 3 by 9 m plots arranged in a randomized complete block design replicated four times. Applications including indaziflam and imazapic significantly decreased dyer's woad plant densities one year following treatment, indicating preemergence management may be powerful in managing biennials as well as annuals. In contrast, elongated mustard densities did not significantly decrease in response to indaziflam applications. Plots treated with chlorsulfuron maintained low elongated mustard plant densities three years after application, but did not significantly reduce dyer's woad plant densities. Spring 2,4-D applications were significantly more effective on elongated mustard plants than fall applications, indicating a fall dormancy period in which foliar applications will be less effective. All treatments effectively suppressed seedbank supplementation and germination in the winter annual life cycle of African mustard. Though the three mustard species are of the same family, variations in life cycle, seedbank longevity, and dormancy patterns influence resilience and susceptibility to herbicide application timings and modes of action.

Understanding Auxin Herbicides for Aquatic Plant Management. Mirella F. Ortiz*, Scott J. Nissen, Franck E. Dayan; Colorado State University, Fort Collins, CO (093)

Hybrid watermilfoil (HWM) is becoming more prevalent in many lakes where Eurasian (*Myriophyllum spicatum*, EWM) and Northern watermilfoil (*M. sibiricum*) co-occur. These hybrids between EWM and the native Northern watermilfoil have a 30% faster growth rate and in many cases are less sensitive to 2,4-D. Among the tools available for EWM and HWM management, chemical control has become a common and cost-effective method for selective management of aquatic plants especially auxinic herbicides, as they are relatively inexpensive and provide consistent control with fewer non-target impacts. Three synthetic auxin mimics are registered for aquatic use: 2,4-D (acid and ester), triclopyr and florpyrauxifen-benzyl. The behavior of the three auxinic herbicides were compared in EWM and HWM by looking at herbicide absorption, translocation to the roots, desorption and metabolism. Herbicide absorption, translocation, and metabolism were evaluated over a 192 h time course, while herbicide desorption was evaluated over a time course of 72 h. The mathematical function that best fit these experimental data were the same for all the herbicides and both watermilfoils; however, florpyrauxifen-benzyl was more rapidly absorbed and reached a higher concentration in the plant. The rate of 2,4-D metabolism to a primary unknown metabolite was similar for EWM and HWM. Herbicide desorbed when treated plant tissue was transferred to clean water and 2,4-D acid and ester desorption was higher based on the initial herbicide absorption compared to triclopyr and florpyrauxifen-benzyl. Based on the herbicide's log K_{ow} more research is needed to fully understand their behavior in aquatic plants.

Selective Control of Flowering Rush in Mesocosms and Field Sites. Gray Turnage*[1], John D. Madsen[2], Ryan M. Wersal[3], John D. Byrd, Jr.[1], Brent Alcott[4], Tera Guetter[5]; [1]Mississippi State University, Starkville, MS, [2]USDA-ARS, Davis, CA, [3]Minnesota State University, Mankato, MN, [4]City of Chaska, Chaska, MN, [5]Pelican River Watershed Association, Detroit Lakes, MN (094)

Flowering rush is an invasive aquatic plant species that is spreading across the northern United States and southern Canada. Flowering rush can displace many native aquatic plant species such as hardstem bulrush, an emergent aquatic plant that is used as spawning habitat by many native fish species. Previous studies show that repeated applications of contact herbicides can control flowering rush; however, it is unknown if these herbicides can be used to selectively control flowering rush co-occuring with hardstem bulrush. The purpose of this study was to determine if selective control of flowering rush was possible with repeat contact herbicide applications in field and mesocosms trials. In field trials, flowering rush leaf density was reduced 99% and 92% at 8 wk after initial treatment (WAIT) in years one and two, respectively, whereas hardstem bulrush leaf density was not affected. In mesocosms, flowering rush and hardstem bulrush were exposed to repeat submersed injections of the contact herbicides diquat, endothall, copper, carfentrazone-ethyl, and flumioxazin. Endothall reduced aboveground biomass of flowering rush by 69% compared to reference plants at 8 WAIT; no other herbicides affected aboveground biomass of flowering rush. Diquat reduced belowground biomass by 77% compared to reference plants at 8 WAIT, but the other herbicides had no effect. None of the herbicides tested in mesocosms affected above- or belowground biomass of hardstem bulrush when compared to nontreated reference plants at 8 WAIT. Future studies should investigate concentration exposure time requirements of endothall and diquat for flowering rush control.

WSWS PROJECT 2: WEEDS OF HORTICULTURAL CROPS

Canada Thistle and Hop Response to Clopyralid Applied with a Sponge Wiper. Marcelo L. Moretti*, David R. King, Ryan Jacob Hill; Oregon State University, Corvallis, OR (110)

Abstract not available

Response of Direct-Seeded Onion and Weed Control with Bicyclopyrone Plus Bromoxynil Premix. Joel Felix*, Joey Ishida; Oregon State University, Ontario, OR (111)

Weed control in onion is very important in order to realize higher yields and bulb quality. Currently, there is lack of herbicides to manage weeds at the early onion growth stage. A field study was conducted starting spring 2020 at Oregon State University, Malheur Experiment Station to evaluate the response of direct-seeded onion cultivar 'Vaquero' and weed control with premix herbicide containing bicyclopyrone plus bromoxynil (Talinor herbicide). The herbicide mixture was applied at various rates when onions were at 1-leaf or 2-leaf stage. The predominant soil was an Owyhee silt loam with a pH of 7.8 and 2.78% organic matter. Treatments included bicyclopyrone 7.96 g ai ha^{-1} + bromoxynil 54 g ai ha^{-1}, bicyclopyrone 15.9 g ai ha^{-1} + bromoxynil 108 g ai ha^{-1}, and bicyclopyrone 19.9 g ai ha^{-1} + bromoxynil 135 g ai ha^{-1} when onions were at 1-leaf growth stage. Other treatments were applied when onions were at the 2-leaf onion growth stage and included bicyclopyrone 19.9 g ai ha^{-1} + bromoxynil 135 g ai ha^{-1}, bicyclopyrone 23.9 g ai ha^{-1} + bromoxynil 162 g ai ha^{-1}, bicyclopyrone 29.8 g ai ha^{-1} + bromoxynil 202 g ai ha^{-1}, or bicyclopyrone 36 g ai ha^{-1} + bromoxynil 244 g ai ha^{-1}. Treatments at the 2-leaf stage were preceded by the delayed pre-emergence application of pendimethalin at 1,060 g ai ha^{-1}. A grower standard comprised of delayed pre-emergence application of pendimethalin at 1,060 g ai ha^{-1} followed by sequential tank mixtures of bromoxynil 210 g ai ha^{-1} + oxyfluorfen 140 g ai ha^{-1} at 2- and 4-leaf growth stages was included. The study area was drip irrigated from April to August and bulbs were harvested in September 2020. Plants were evaluated for visible injury and plots were evaluated for the level of weed control. Evaluations at

7 days after 1-leaf application indicated no onion injury and <4% to 18% across treatments for the 2-leaf application timing. A tank mixture of insecticides spirotetramat + azadidirachtin + a methylated seed oil adjuvant applied 17 days after bicyclopyrone + bromoxynil at the 2-leaf timing resulted in onion injury ranging from 28 to 65% across rates. No injury was observed on plants treated with bicyclopyrone + bromoxynil at 1-leaf stage (28 days before insecticides were applied). The highest marketable onion yield (129.5 to 144 Mg ha^{-1}) was observed when bicyclopyrone + bromoxynil was applied to plants at the 1-leaf growth stage. Marketable onion yield was reduced to 116.4 to 92.1 Mg ha^{-1} across rate gradient when bicyclopyrone + bromoxynil was applied at the 2-leaf stage. Injury from insecticide application to plants in treatments applied at the 2-leaf stage likely contributed to reduced marketable yield. Yield for small onion size (<5.7 cm in diameter) increased from 0.3 to 0.6 Mg ha^{-1} across treatments applied at the 1-leaf stage to 1.6 to 2.5 Mg ha^{-1} for treatments applied when onions were at the 2-leaf growth stage. These results indicated onion tolerance to bicyclopyrone + bromoxynil applied when onions were at the 1-leaf growth stage. In order to avoid injury, follow up studies will explore the best interval between bicyclopyrone + bromoxynil application at the 2-leaf growth stage and application of insecticide to control thrips.

Pendimethalin Application Methods in Onion. Harlene M. Hatterman-Valenti*, Collin Auwarter; North Dakota State University, Fargo, ND (112)

Field studies were conducted at a grower's field near Oakes, ND to evaluate crop safety and weed control when applying pendimethalin as a delayed preemergence, or early postemergence to onion (*Allium cepa*) in comparison to growers' standard practices. One long-day onion cultivar, Hamilton was planted April 28, 2020 as 20 cm rows and a planting population of 462,500 seeds ha^{-1}. First preemergence applications were applied 10 days after planting (DAP), when the onion pellet was cracking and radical beginning to emerge. Early postemergence applications occurred while onions were in the loop stage on May 24 (24 DAP). The first maintenance spray application was June 2 (35 DAP) with GoalTender at 0.29 L ha^{-1} when onions were at the one-leaf-stage. Approximately three weeks later on June 22, the second maintenance application (55 DAP) with Chateau at 525 gm ha^{-1} occurred while the onions were in the four-leaf-stage. Early-season weed control was excellent with all treatments and no injury was observed except for the Nortron 3.5x treatment, which stunted, caused chlorosis, and eliminated some of the onions. This treatment had the lowest total yield at 22.8 Mg ha^{-1}, but was only approximately 6% lower than the onion total yield for the Prowl H2O delayed preemergence treatment, the next lowest total yield. The greatest total yield was 38.8 Mg ha^{-1} when treated with Satellite HydroCap 0.88 L ha^{-1} 10 DAP. However, this did not differ from the total yields from any of the other herbicide treatments except the two lowest total yields previously mentioned. Additional trials are planned to examine the consistency of crop safety and weed control when pendimethalin is applied preemergence, delayed preemergence, or early postemergence since all three application methods generally performed well at both locations.

Intelligent Weed Management in California Lettuce Production. Elizabeth G. Mosqueda*[1], Steven A. Fennimore[2], Richard Smith[3]; [1]California State University-Monterey Bay, Marina, CA, [2]University of California, Davis, CA, [3]University of California Division of Agriculture and Natural Resources, Salinas, CA (113)

Weeds are one of the most problematic pests in California leafy green systems. Alternative methods of weed control for lettuce production are needed because of increasing costs of hand labor and few registerd herbicides for these systems. FarmWise® Titan and NAIO® Dino weeders are two of the newest automated weeders to California's Salinas Valley lettuce industry. They differ from other automated weeders as they are autonomous, therefore they do not need an on-board driver to navigate a field as they weed. Field studies were conducted throughout the Salinas Valley during the 2020 lettuce season to evaluate the potential of autonomous weeders for use in lettuce systems. Field trials were set up in seven commercial lettuce fields and plots were weeded with either a standard inter-row cultivator or an autonomous weeder. To estimate weed control efficacy, weed counts were performed within a six-inch band of each lettuce seedline one day before and one day after treatments took place. The number of lettuce before and after treatment was also collected. To estimate the amount of time it took to remove supplemental weeds left behind by both treatments, the time it took to hand weed each treatment was collected. Yield was estimated by collecting average head weights of lettuce at harvest. Data was analyzed using a paired T-test. Autonomous weeders removed significantly more weeds compared to standard cultivation (P-value < 0.001), with an average of 59.2% and 31.5% of all weeds removed within the target zone, respectively. Treatment did not impact the lettuce stand (P-value=0.16), with nearly 99% of all lettuce plants remaining after treatment took place for either treatment. The amount of time it took to remove supplemental weeds by hand after treatment was not significantly different (P-value=0.195), with plots weeded by autonomous weeders and standard cultivation averaging 7.26 hours/acre and 11 hours/acre to weed, respectively. Treatment did not impact average lettuce head weight at harvest (P-value=0.913), with both treatments resulting in lettuce that averaged nearly 1.8 lbs. at harvest.

Florpyrauxifen-benzyl for Orchard Floor Weed Management in Tree Nuts. Jesse M. Richardson*[1], Stephen F. Colbert[2], Sunil Tewari[3]; [1]Corteva Agriscience, Mesa, AZ, [2]Corteva Agriscience, Escalon, CA, [3]Corteva Agriscience, Madera, CA (114)

Paper withdrawn

My Experience Using Video Recordings of Potato Research Trial Plot "Walk-Throughs" for Virtual Weed Control Tours: the Good, the Not Too Bad, and the Definitely Not Ugly. Pamela J.s. Hutchinson*; University of Idaho Aberdeen R & E Center, Aberdeen, ID (115)

Virtual meetings. Virtual tours. Recorded presentations. Zoom. Some of us had an uphill climb learning how to be effective weed science researchers, extension specialists, and instructors without face-to-face interactions. Field research trial "Walkthrough Videos" helped this research and extension specialist get the tours to the people rather than the people to the tours. With iPad Pro in hand, the videos seemed at first, relatively easy. Putting them into the "Virtual" was the challenge. Going from raw footage with no sound because of the noisy wind, to voice-overs in simple PowerPoint slide shows resulted in some nice work. The use of good video production software to trim, splice, insert still photos and charts plus add titles and audio including music took the "walkthroughs" to new places. These newly learned skills will be put to use in the future even at in-person events.

Mustard Cover Crop for Early Season Weed Control in Chile Pepper. Akash Bajagain*, Brian Schutte, Erik A. Lehnhoff, Robert Steiner; New Mexico State University, Las Cruces, NM (127)

The objective of this study was to determine the optimum time for terminating a mustard cover crop before seeding chile pepper. To accomplish this objective, a mixture of *Brassica juncea* and *Eruca sativa* was seeded at 14 kg ha^{-1} and the standing biomass was incorporated into soil at 8, 6 and 4 wk before crop seeding. The study also included a non-cover control treatment. For each cover-crop treatment, pre-emergence herbicides clomazone or napropomide were applied at full label rates at crop seeding. At 14-d intervals after crop seeding, weed densities were determined. Hand hoeing times were determined at 28 and 56-d after crop seeding (DAS). Results indicated that cover crop termination time effects on weed densities and hoeing were conditioned by herbicide. For napropomide, cumulative weed densities and hand-hoeing times at 28 DAS were less than the non-cover control only when mustard was terminated 6 wk before chile pepper seeding. For clomazone, weed densities and hand hoeing times at 28 DAS were similar between the non-covered control and mustard treatments. At 56 DAS, cumulative weed densities and hand hoeing times were not affected by cover crop treatment. These results suggest (1) weed control benefits derived from mustard cover crops are conditioned by pre-emergence herbicide and cover crop termination time, and (2) those benefits diminish after early phases of chile growing season. A mustard cover crop terminated 6 wk before crop seeding, followed by napropamide applied at crop seeding, is a promising strategy to reduce early season weeds in chile pepper.

WSWS PROJECT 3: WEEDS OF AGRONOMIC CROPS

Sequential PRE/POST Application Timing of Dimethenamid-P to Control ALS-Inhibitor-Resistant Palmer Amaranth in Dry Edible Bean. Joshua Wa Miranda Teo*[1], Jeff Bradshaw[1], Amit J. Jhala[2], Nevin Lawrence[1]; [1]University of Nebraska, Scottsbluff, NE, [2]University of Nebraska, Lincoln, NE (080)

Palmer amaranth (*Amaranthus palmeri*) is becoming more prevalent in Western Nebraska, where ALS-inhibitor-resistant biotypes are widespread. There are no effective dry edible bean POST herbicides labeled for ALS-inhibitor-resistant Palmer amaranth control. A study was conducted in Scottsbluff, NE in 2019 and 2020 to evaluate dimethenamid-P efficacy in a sequential PRE/POST program at two POST application timings, V1 and V3, for controlling ALS-inhibitor-resistant Palmer amaranth in dry edible bean. In 2019, all treatments included a PRE application of pendimethalin + dimethenamid-P. POST treatments included a non-treated; imazamox + bentazon + fomesafen; imazamox + bentazon + fomesafen + dimethenamid-P; and dimethenamid-P, all applied at V1 and V3 growth stages. In 2020, treatments included a non-treated check and PRE applications of pendimethalin + dimethenamid-P. POST treatments included a non-treated (PRE-only); imazamox + bentazon; imazamox + bentazon + dimethenamid-P; imazamox + bentazon + fomesafen; and dimethenamid-P, all applied at V1 and V3. Dimethenamid-P applied POST provided Palmer amaranth season-long control at both V1 and V3 timings in 2020, but effective control of Palmer amaranth only occurred at the V1 timing in 2019. Palmer amaranth was able to emerge prior to the V3 application in 2019. PRE herbicide longevity may vary every year along with the timing of Palmer amaranth emergence, depending on environmental conditions. Using dimethenamid-P in a sequential PRE/POST program can be an effective alternative to POST herbicides, with a V1 application timing providing consistent control.

Effect of Winter Wheat Cover Crop Termination Time on Dry Bean Production. Tyler C. Hicks*, David A. Claypool, Andrew R. Kniss; University of Wyoming, Laramie, WY (081)

Direct harvest of dry edible beans is becoming more common in Wyoming and Western Nebraska. Cover crops are often promoted for weed suppression, and past research has shown that the presence of a cover crop increases dry bean node and pod heights. The objective of this study was to evaluate the effect of cover crop termination timing on bean pod heights, yield, and direct harvest yield loss. Field studies were conducted in 2019 and 2020 near Lingle, Wyoming. Three dry edible bean varieties were chosen based on preliminary pod height data: 'Lariat' (tall variety), 'Othello' (low variety), and 'Staybright' (intermediate variety). Beans were planted directly into a winter wheat cover crop which was terminated at different timings ranging from 30 days before planting to 28 days after planting. The experimental design was a split-plot treatment arrangement of winter wheat termination timing and bean variety set in a randomized complete block design with 8 replicates. Generally, if the cover crop was terminated later than 2 days before through 2 days after planting it increased first trifoliolate height for all varieties. Bean yield decreased if the cover crop was terminated 10 days after planting or later for the Othello and Staybright varieties. There is a window for cover crop termination to effect harvest efficiency without negatively impacting bean yield between 2 and 10 days after planting.

Hemp Canopy Light Interception and Injury with Pre-Emergence Herbicides. Joseph E. Mettler*; North Dakota State University, Fargo, ND (082)

Hemp (*Cannabis sativa* L.) production in the U.S decreased 9% in the past year in part due to regulatory and market uncertainties, but also due to harvest complications, seed contamination, and yield loss due to weeds. No herbicides are currently labeled for use in industrial hemp in the U.S. In 2019 and 2020, experiments were conducted near Fargo, ND to evaluate pre-emergence herbicides for crop safety, canopy light interception, and yield. Cultivar X-59 was planted into a randomized complete block design with four replicates at four locations. Herbicides were applied at typical 1x rates for other crops. Visible crop injury was evaluated on a scale of 0 to 100% at 14 and 28 days after emergence (DAE). Light interception was measured with an AccuPAR ceptometer at 14, 28, and 49 DAE and at harvest. All herbicides resulted in crop injury. However, pendimethalin, trifluralin, quinclorac, and pyroxasulfone resulted in only 6 to 10% injury at all evaluation timings. Light interception of the hand-weeded was similar to hemp treated with imazethapyr, trifluralin, saflufenacil, and acetochlor. Grain yield was not different among treatments and averaged 1940 kg ha^{-1}. A correlation analysis was conducted showing that percent injury had a weak negative correlation to light interception (<-0.40) and yield (<-0.30). Light interception had a moderately positive (0.40-0.77) correlation to yield at the different evaluation timings. Hemp was resilient to 20% injury or less from pre-emergence herbicides.

Residue tests need to be conducted to confirm pre-emergence herbicide safety and aid in product registration.

Metribuzin Tolerance of Southern Great Plains Winter Wheat Varieties. Lane S. Newlin*[1], Misha R. Manuchehri[1], Brett F. Carver[1], Amanda De Oliveira Silva[1], Hannah C. Lindell[1], Justin T. Childers[2], Caitlyn C. Carnahan[1]; [1]Oklahoma State University, Stillwater, OK, [2]Oklahoma State University, Marlow, OK (083)

Metribuzin is a herbicide that is still widely used in cropping systems annually. However, its use in winter wheat in Oklahoma has declined due to varietal sensitivity or lack of information regarding the topic. To evaluate modern winter wheat varieties, a trial was conducted at Fort Cobb and Perkins, Oklahoma in the fall of 2019. Winter wheat varieties Fusion AX, Showdown, Strad CL Plus, and Uncharted were evaluated. Treatments consisted of two herbicide tank mixtures and a control. Mixtures included pyroxasulfone at 119 g ai ha^{-1} plus 105 or 210 g ai ha^{-1} of metribuzin. Herbicide mixtures were applied PRE or delayed PRE (wheat spike). Visual wheat injury, biomass, and crop yield were recorded. For peak visual crop injury at both locations, damage following 105 g ai ha^{-1} and 210 g ai ha^{-1} of metribuzin was between 25 and 44%, and 31 and 57%, respectively. For yield at Fort Cobb, there was an application timing by metribuzin rate interaction where only the high rate applied PRE reduced yield. For yield at Perkins, a variety by metribuzin rate interaction occurred where compared to the nontreated, there was a reduction in yield for Strad CL Plus following the low metribuzin rate. Following the high rate compared to the control, there was a reduction in yield for all varieties except Showdown. Results suggest that metribuzin can be used in winter wheat to effectively control economically important grass weeds, but soil type, variety, application timing, and rate must be considered.

Tillage System Impact on Efficacy of Delayed Preemergence Herbicides in Winter Wheat. Grace Flusche Ogden*, Misha R. Manuchehri, Jason G. Warren; Oklahoma State University, Stillwater, OK (084)

Delayed PRE herbicides can provide season-long Italian ryegrass (*Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot) control in Oklahoma winter wheat when applied at proper rates and successfully incorporated. However, heavy previous crop residue found in reduced tillage systems may reduce efficacy. Some herbicide labels describe this, and producer sentiments echo it. A study was conducted during the 2019-20 and 2020-21 seasons near Stillwater, Oklahoma to evaluate the efficacy of delayed PRE herbicides in no-till, conservation, and conventional wheat tillage systems. Conservation tillage was comprised of a single pass of a sweep plow set approximately 10 cm below the soil surface with a rotary hoe following behind. The conventional tillage system was disked twice with a tandem disk prior to planting. Plots were maintained weed free throughout the summer fallow period with burndown herbicide applications as needed. Herbicide treatments consisted of metribuzin, pinoxaden, pyroxasulfone, and/or pyroxasulfone + carfentrazone-ethyl applied alone or in tank-mixture. No tillage by herbicide interaction was observed for visual crop injury, weed control, or wheat yield. Significant crop injury for pyroxasulfone + metribuzin was observed in 2019. No visual crop injury was noted in 2020, likely due to delayed rains. In both years, ryegrass control greater than

92% was achieved following treatments of pyroxasulfone + metribuzin and pyroxasulfone + pinoxaden. Soil surface residue as influenced by tillage did not affect the efficacy of delayed PRE herbicides in winter wheat. With a wide range of tillage systems across Oklahoma, these results may influence use of PRE herbicides moving forward.

Effect of Planting Date Window and Herbicide Selection on Rescuegrass (*Bromus catharticus*) Management in Winter Wheat. Hannah C. Lindell*[1], Misha R. Manuchehri[1], Todd A. Baughman[2], Emi Kimura[3], Brett F. Carver[1], Lane S. Newlin[1], Caitlyn C. Carnahan[1], Justin T. Childers[1]; [1]Oklahoma State University, Stillwater, OK, [2]Oklahoma State University, Ardmore, OK, [3]Texas A&M University Extension, Vernon, TX (085)

Rescuegrass (*Bromus catharticus)* is an early emerging winter annual grass weed prevalent in winter wheat production of the southern Great Plains. Growers can successfully manage rescuegrass in herbicide tolerant wheat systems; however, control in non-herbicide tolerant wheat often is poor. To evaluate integrated management of rescuegrass and other *Bromus* spp., a study was conducted at Marshall and Lahoma, Oklahoma and Burkburnett, Texas to assess an early, mid-, and late planting date, one high-competitive and one low-competitive wheat variety, and two common herbicides: sulfosulfuron at 35.2 g ai ha^{-1} and pyroxsulam at 18.4 g ai ha^{-1}. The earliest date represented optimal sowing window for grain only wheat production. At Marshall, mid- and late planting dates decreased rescuegrass biomass 19 and 23 g per 0.25 m^{-2}, respectively, compared to the early planting date. At Burkburnett, a reduction in downy brome (*Bromus tectorum*) biomass was observed for the late planting date, reducing biomass by 28 and 37.6 g more than mid or early date, respectively. Pyroxsulam controlled rescuegrass best at Marshall by decreasing biomass 28 g more than sulfosulfuron. Although, sulfosulfuron had better control at Burkburnett by decreasing rescuegrass biomass 5.5 g more than nontreated. True cheat (*Bromus secalinus L*.) and downy brome biomass decreased 98% after both pyroxsulam and sulfosulfuron treatments at Lahoma. Treatments of pyroxsulam or sulfosulfuron and a delay in planting by two to six weeks after the early sowing time did provide a reduction in rescuegrass biomass.

Metabolic Resistance to PPO-inhibitors in a Six-way-resistant Palmer Amaranth Population from Kansas. Ednaldo A. Borgato*, Chandrima Shyam, Balaji Aravindhan Pandian, Sathishraj Rajendran, Dallas E. Peterson, Anita Dille, Mithila Jugulam; Kansas State University, Manhattan, KS (086)

Palmer amaranth (*Amaranthus palmeri* S. Watson) is a major weed in the US and many populations have evolved resistance to multiple herbicide sites of action (SOA). Recently, a population from a long-term conservation tillage study in Kansas (KCTR) has been confirmed to be resistant to six SOAs (glyphosate, 2,4-D, ALS-, HPPD-, PSII-, and PPO-inhibitors), with predominance of metabolic-based resistance to several herbicides. The objectives of this research were to determine the level of resistance and investigate the mechanism imparting resistance to the protoporphyrinogen oxidase (PPO)-inhibitor lactofen in KCTR Palmer amaranth. A dose-response assay was performed in greenhouse to determine the relative level of resistance to lactofen and to assess the effect of a P450-inhibitor (malathion) on the herbicide treatment in KCTR. To determine the presence of target site mutations, the *PPO2* gene (molecular target of

PPO-inhibitors) from resistant and susceptible plants was sequenced. Dose-response analysis confirmed resistance to lactofen in KCTR. Treatment with malathion and lactofen reversed the resistance, indicating the involvement of P450 with lactofen metabolism. The sequence alignment of *PPO2* gene did not show any previously reported or novel mutations conferring resistance to PPO-inhibitors. Summarizing, these results confirm metabolic resistance to lactofen in KCTR Palmer amaranth. Future work involves the profiling of lactofen metabolites, and investigation of the genetic basis of resistance to PPO-inhibitors in KCTR.

Fall-Established Cover Crop Tolerance to Soybean Herbicides. Gregory J. Endres*[1], Kirk A. Howatt[2], Mike Ostlie[1], Joseph E. Mettler[2]; [1]North Dakota State University, Carrington, ND, [2]North Dakota State University, Fargo, ND (116)

A field study was conducted during 2018-20 at North Dakota State University near Fargo and the Carrington Research Extension Center to evaluate the response of cool-season cover crops following herbicides with soil residue previously used for soybean. Experimental design was a randomized complete block with a split-plot arrangement (whole plot=herbicide and sub-plot=cover crop) and three or four replications. The core group of herbicides used in the study: flumioxazin, imazethapyr, metribuzin, pyroxasulfone, sulfentrazone (PRE); and dicamba and fomesafen (POST). Additional herbicides included glufosinate and imazamox (POST), and herbicide tank-mixture of sulfentrazone/fomesafen (PRE/POST). Herbicides were applied at labeled rates and timing for weed management for last-half May planted soybean. Soybean at seed-development growth stages were terminated in August by mowing, and cover crops were direct-seeded into soybean stubble generally late August to early September. The core group of cover crops evaluated in the study were barley, winter rye, field pea, flax, radish, and turnip; others included canola/rapeseed and lentil. Cover crop response to herbicide residues was visually evaluated as reduction in biomass and plant stand 2 to 4 and 6 to 8 wk after plant emergence (generally 3 to 4 mo after application of herbicides). All herbicides injured cover crops, but not consistently. Cover crop injury greater than 20 percent occurred with flumioxazin, imazethapyr, metribuzin, pyroxasulfone, sulfentrazone, and fomesafen. Cover crops with injury greater than 20 percent included radish, turnip and canola/rapeseed. Cover crops with injury less than 20 percent included barley, winter rye and field pea. A table summarizing the study results is available in the 2021 ND Weed Control Guide (https://www.ag.ndsu.edu/weeds/weed-control-guides/2021%20nd-weed-control-guide-1/2021-nd-weed-control-guide/view).

Picking on the Panicle - a New Management Timing Opportunity for Wild Oat (*Avena fatua*). Breanne D. Tidemann*[1], K Neil Harker[2], Steve Shirtliffe[3], Christian Willenborg[3], Eric N. Johnson[3], Elizabeth Sroka[1], Jennifer Zuidhof[1]; [1]Agriculture and Agri-Food Canada, Lacombe, AB, Canada, [2]Boulder County Open Space, Lacombe, Canada, [3]University of Saskatchewan, Saskatoon, SK, Canada (117)

Novel management strategies are needed to combat and manage herbicide resistant wild oat. A two-year study was conducted in Lacombe, AB in 2015-2016 and 2016-2017 comparing hand clipping of the panicle, to removal by a cutter bar, and a selective crop-topping treatment in wheat. All treatments were applied either at panicle emergence (90% of panicles in a plot emerged), at initiation of seed shed, or at both timings in a combination treatment. Wild oat dockage and viability were measured in the first year, and wild oat population density, biomass and seedbank, as well as crop yield were measured in the subsequent canola year. Preliminary results study suggest that the selective crop topping treatment was the most effective panicle targeting method, and early implementation of any of the treatments tended to be more effective than late treatments. However, impact of the clipping/cutter bar treatments on the subsequent wild oat population was limited. This is likely due to smaller scale reductions in seedbank inputs from cutting of panicles in a single year, particularly in a weed species with a dormant seed bank and in a taller crop such as wheat. Selective crop topping was very successful at decreasing the population, and resulted in wild oat populations similar to standard in-crop herbicide applications. The crop-topping treatment used in the study would not be recommended for producer use as is due to label restrictions, potential crop injury or maximum residue limit (MRL) issues, as well as existing biotypes with resistance to the product used. However, these studies indicate an opportunity to target the wild oat panicle with alternative management strategies, particularly those that can be translocated or conducted throughout the entire wild oat plant.

Precision vs. Uniform Spraying for Broadleaf Weed Control. Judit Barroso[1], Nicholas G. Genna*[2]; [1]Oregon State University, Adams, OR, [2]Oregon State University, Pendleton, OR (118)

Precision spraying systems have the potential to reduce chemical and water usage with resultant cost and time savings. However, efficacy may be reduced in instances where complete weed coverage is not achieved due to sub-optimal sensor detection. This research was carried out to compare herbicide efficacy between WEEDit and WeedSeeker, two sensors distributed most worldwide to spot spray weeds, and uniform spraying in fallow and post-harvest trials in 2019 and 2020 at the Columbia Basin Agricultural Research Center in Pendleton, Oregon. Additionally, each spray system was compared with different weed communities: natural, natural + Russian thistle, and natural + kochia. Furthermore, in a different trial, each spray system was studied with differing residue management including a short and tall stubble, and a regular stubble height where the chaff and straw was collected behind the combine with a tarp. Glyphosate (GlyStar®) and bromoxynil + pyrasulfotole (Huskie®) were tested in the fallow and post-harvest trials while only bromoxynil + 2,4-D (Deadbolt®) was used in the residue management trial. Herbicides were applied at the same rate across spray systems and spring wheat stubble was used in all post-harvest treatments. Herbicide efficacy was calculated as the percentage decrease in density and coverage at 3 and 6 weeks after treatment. Overall, uniform spraying demonstrated greater efficacy across post-harvest treatments in 2019 and 2020 and in fallow in 2019 compared to precision spraying. However, WEEDit provided higher or similar efficacy to uniform spraying in the 2020 fallow trials. No effect was detected between residue management treatments. This research demonstrates that optimal performance of precision spraying systems can provide similar efficacy to uniform spraying in fallow but that efficacy in post-harvest applications may be reduced. Further research is necessary to understand what factors limit the efficacy of precision spraying systems to encourage adoption by farmers.

Influence of Sodium on Glyphosate Performance and Interaction with AMS Adjuvants. Gregory K. Dahl*[1], David A. Van Dam[2], Martin M. Carr[3], Errin M. Willenborg[3], Amanda Flipp[4], Laura J. Hennemann[4], Joshua J. Skelton[4]; [1]Winfield United, Eagan, MN, [2]Winfield

United Canada, Winnipeg, MB, Canada, [3]Winfield United Canada, Saskatoon, SK, Canada, [4]Winfield United, River Falls, WI (119)

Water quality testing was conducted in 2018 through 2020 in Canada. The water quality reports used coefficients from research at North Dakota State University to recommend the amount of ammonium sulfate, AMS, needed to be to overcome antagonism of glyphosate from cations. The AMS amounts recommended were adequate to overcome the antagonism. Many water quality reports indicated the samples contained more than 500 ppm sodium. Many of the samples did not contain high levels of calcium or magnesium and were not considered hard. Studies were conducted to determine the influence of sodium cation concentration on glyphosate. Spray water samples were made using distilled water and various amounts of sodium chloride. The target waters were to be distilled water, 125 ppm sodium, 250 ppm sodium, 500 ppm sodium and 1000 ppm sodium. Glyphosate was sprayed at 434 g ae/ha with a hand boom with AIXR 110015 flat fan nozzles at 100 liters per hectare. Each of the glyphosate plus water samples were sprayed with no adjuvant, 34% AMS at 2.5% v/v or an adjuvant which contains a nonionic surfactant plus 34% liquid AMS at 2.5% v/v. Control of velvetleaf, *Abutilon theophrasti Medik, and common lambsquarters, Chenopodium album L* was decreased as sodium cation concentration increased when no adjuvant was present. The nonionic surfactant plus AMS adjuvant and the AMS adjuvant increased velvetleaf control when distilled water was used compared to glyphosate alone. Both nonionic surfactant plus AMS adjuvant and the AMS adjuvant were able to prevent the reduction in velvetleaf control as sodium concentration increased. The nonionic surfactant plus AMS adjuvant increased common lambsquarters control when distilled water was used compared to glyphosate alone or with just AMS. The nonionic surfactant plus AMS adjuvant was able to reduce or prevent the reduction in common lambsquarters control as sodium concentration increased.

Tame Mustard and Buckwheat Response to Various Herbicides. Kirk A. Howatt*[1], Joseph E. Mettler[1], Caleb D. Dalley[2]; [1]North Dakota State University, Fargo, ND, [2]North Dakota State University, Hettinger, ND (120)

Market interest for mustard and buckwheat seed commodities is increasing. However, growers are reluctant to invest in these market potentials because of limited herbicide options to control weeds, especially in production systems that limit or eliminate tillage. Field experiments were established at Fargo and Hillsboro in eastern North Dakota and Hettinger in southwest North Dakota to identify herbicides with potential for use in these crops. Separate experiments were established for PRE (nine candidates) and POST (fifteen candidates) herbicides with rates typical to each location for weed control in other crops. Strips of both species were seeded perpendicular to herbicide in each replicate but analysis (F-protected LSD at a=0.05) was conducted by species. Multiple evaluations occurred but discussion was based on evaluation approximately 1 MAT. For PRE herbicides, pendimethalin resulted in less than 10% mustard injury across locations. Metolachlor or dimethenamid could be viable for either crop, but injury to mustard at Hillsboro exceeded 20%. Metribuzin, pyroxasulfone, and mesotrione resulted in less than 20% injury to buckwheat. In POST experiments, ethometsulfuron, clopyralid, and quinclorac generally resulted in less than 20% injury to both species. Halauxifen produced little response from mustard but as much as 80% injury in buckwheat. Flumiclorac and pyraflufen also resulted in less than 20%

injury to mustard. Several options were identified for further evaluation and development with industry partners.

Rush Skeletonweed (*Chondrilla juncea*) Control in Winter Wheat Fallow. Mark E. Thorne*, Drew J. Lyon; Washington State University, Pullman, WA (121)

Rush skeletonweed (*Chondrilla juncea*) spread to eastern Washington farmland during the Conservation Reserve Program (CRP) starting in the 1980s and persisted when CRP contracts expired, and the land was again farmed. Rush skeletonweed is a deep-rooted perennial that depletes soil moisture during the fallow year of wheat/fallow rotations, which can result in reduced wheat seed germination and reduced yield. We initiated a study to compare herbicides with some known activity on rush skeletonweed in a tillage fallow system near LaCrosse, WA in October 2107. The main objective was to control rush skeletonweed through the fallow year of the rotation. We compared fall and spring applied treatments and an early-summer application at plant bolting. Herbicides included clopyralid (280 g ae ha^{-1}), aminopyralid (21 g ae ha^{-1}), picloram (280 g ae ha^{-1}), glyphosate (2522 g ae ha^{-1}), clopyralid/2,4-D (213/1121 and 107/561 g ae ha^{-1}), chlorsulfuron/metsulfuron (17.5/3.5 g ai ha^{-1}), and 2,4-D (2056 g ae ha^{-1}). We added two identical trials in 2018, but each in chemical fallow systems. Each trial was a randomized completed block design with four replications per treatment. Fall-applied picloram resulted in the lowest density of rush skeletonweed, overall. Spring-applied clopyralid or aminopyralid resulted in the lowest density in the following winter wheat crop at both chemical fallow sites but were not effective at the tillage fallow site. This was likely because of spring frosts and freezes that occurred within ten days following application at the tillage fallow site, but not at the chemical fallow sites. Fall-applied phenoxy herbicides were more effective when frosts or freezes preceded applications within five days. Glyphosate was not effective for long-term control. Winter wheat yields were well above average, so no yield reduction was observed in the nontreated check, and yield was not reduced by the picloram application. Control in fallow was not 100% with any treatment, so effective control in the wheat crop, and growing a competitive wheat crop will be important for long-term management of rush skeletonweed.

Control of Multiple Herbicide-Resistant Kochia in Fallow. Vipan Kumar*[1], Taylor Lambert[1], Phillip W. Stahlman[1], Randall S. Currie[2], Bob Bruss[3]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Garden City, KS, [3]Nufarm Americas, Morrisville, NC (122)

Evolution of multiple herbicide-resistant (MHR) kochia is a serious concern across North American Great Plains. Kochia resistant to glyphosate, chlorsulfuron, and dicamba has become quite common in recent years, whereas multiple resistance to additional herbicides, including fluroxypyr, atrazine, and metribuzin has also been reported. Effective management of these MHR kochia populations warrants the development of alternative herbicide strategies. The main objectives of this research were to (1) determine the effectiveness of dichlorprop-p, 2,4-D LV4 and dicamba alone or in various combinations for MHR kochia control, and (2) investigate the interaction of dichlorprop-p, 2,4-D LV4, dicamba, and/or halauxifen/fluroxypyr in various combinations for controlling MHR kochia. To meet these objectives, greenhouse and field experiments were conducted at Kansas State University Agricultural Research Center in Hays, KS. Greenhouse study included a MHR kochia accession (resistant to glyphosate/dicamba

/fluroxypyr/chlorsulfuron/atrazine/metribuzin) from Garden City, KS and a susceptible (SUS) kochia accession from Hays, KS. Kochia plants from both populations were separately grown in 10-cm squared plastic pots containing commercial potting mixture in greenhouse. Treatments, including dicamba (280 g ha^{-1}), 2,4-D LV4 (286 g ha^{-1}), dichlorprop-p (560 g ha^{-1}) alone or in various combinations were tested on 8 to 10 cm tall plants from MHR and SUS populations. Field experiments were conducted in fallow ground (soybean stubble) and field site had a natural infestation of kochia population with multiple resistance to glyphosate and dicamba. Herbicide treatments, including dichlorprop-p (560 g ha^{-1}), 2,4-D LV4 (538 g ha^{-1}), dicamba (560 g ha^{-1}), and/or halauxifen/fluroxypyr (5/122 g ha^{-1}) were tested alone or in various tank-mix combinations (2 or 3-ways) for control of MHR kochia. Both greenhouse and field experiments were conducted in randomized complete block design (RCBD) with 12 and 4 replications, respectively. Data on percent visible control and shoot biomass of MHR and SUS kochia were recorded at 3 weeks after treatment (WAT) in greenhouse study, whereas only visible control data were assessed on biweekly basis in field study. Results from greenhouse study indicated that dicamba, dichlorprop-p, and 2,4-D LV4 applied alone provided inadequate control (5 to 42%) of MHR kochia. In contrast, control of SUS population was 83 to 92% with dicamba and dichlorprop-p alone treatments. Tank-mixing dicamba with dichlorprop-p and dichlorprop-p + 2,4-D LV4 significantly improved visible control (72 to 90%) of MHR kochia as compared to dicamba (42%) alone treatment. Results from field study indicated that addition of dicamba to dichlorprop-p or halauxifen/fluroxypyr (two-way mixtures) and to dichlorprop-p + 2,4-D LV4, halauxifen/fluroxypyr + dichlorprop-p or halauxifen/fluroxypyr + 2,4-D LV4 (three-way mixtures) provided excellent control (91 to 97%) of MHR kochia compared to dicamba, halauxifen/fluroxypyr, 2,4-D LV4, and dichlorprop-p alone treatments. In conclusion, these preliminary results suggested that tank-mixing dichlorprop-p with other auxinic herbicides, including dicamba, and halauxifen/fluroxypyr can potentially provide synergistic effect in controlling MHR kochia. To our knowledge, this study documents the first report of potential synergism between dicamba and dichlorprop-p herbicide on MHR kochia.

Distribution of Herbicide-Resistant Kochia in Southcentral Great Plains. Rui Liu*[1], Vipan Kumar[1], Taylor Lambert[1], Misha R. Manuchehri[2], Muthukumar V. Bagavathiannan[3], Randall S. Currie[4], Phillip W. Stahlman[1]; [1]Kansas State University, Hays, KS, [2]Oklahoma State University, Stillwater, OK, [3]Texas A&M University, College Station, TX, [4]Kansas State University, Garden City, KS (123)

Kochia (*Bassia scoparia*) is one of the most problematic broadleaf weed species in the southcentral Great Plains, including western Kansas (KS), western Oklahoma (OK) and northern Texas (TX). Evolution of herbicide-resistant (HR) kochia populations is a significant concern to the crop production. To develop effective kochia control strategies, it is important to understand the geographical distribution and existing frequency of herbicide resistance among kochia populations in the region. Seeds of about 110 kochia populations were collected in a random field survey from 3 states. The main objective of this research was to understand the resistance frequency (% survival) in selected kochia populations from 3 states to field-use rate of glyphosate, chlorsulfuron, atrazine, dicamba and fluroxypyr. Seedlings of selected kochia populations (17 from KS, 13 from OK, and 6 from TX) were grown in 50-cell (one seedling per cell) germination trays (one tray per population per herbicide) in a greenhouse at Kansas State University Agricultural Research Center in Hays, KS. Each population was separately treated with glyphosate (1260 g ha^{-1}), chlorsulfuron (26 g ha^{-1}), atrazine (1120 g ha^{-1}), dicamba (560 g ha^{-1}), and fluroxypyr (235 g ha^{-1}) in a spray chamber when kochia plants were 8 to 10 cm tall. Data on dead and live counts were recorded at 21 days after treatment (DAT). Percent survival frequency within each population was estimated for each herbicide. Based on = 20% survival frequency cutoff, the resistance to chlorsulfuron and glyphosate was observed in all 17 KS populations, with survival frequency of 57 to 96% for chlorsulfuron and 43 to 89% for glyphosate. Resistance to dicamba was observed in 14 populations, with survival frequency ranging from 25 to 88%. In comparison, only 2 KS populations showed resistance to fluroxypyr, with survival frequency of 36% and 43%. Similar resistance frequency trends were observed in OK and TX populations for chlorsulfuron and glyphosate. Six out of 13 OK populations showed resistance to dicamba, with survival frequency ranging from 24 to 94%, whereas only one out of the 13 showed resistance to fluroxypyr. All six kochia populations from TX had resistance to dicamba (survival frequency 38 to 76%) and fluroxypyr (60 to 88%). Atrazine resistance was found in 9 OK and 5 TX populations. These preliminary results suggested that single and multiple resistance to glyphosate, chlorsulfuron, dicamba and fluroxypyr exist in Kochia populations from southcentral Great Plains. Growers should proactively adopt diversified kochia control practices, including the use of effective alternative soil residual (PRE) and POST herbicides, competitive crop rotations, occasional tillage, and cover crops to manage HR kochia on their production fields.

Investigation of Herbicide Resistance in Palmer Amaranth (*Amaranthus palmeri*) Introduced Through Sunflower Screenings. Joseph T. Ikley*, Nathan H. Haugrud, Stephanie A. DeSimini; North Dakota State University, Fargo, ND (124)

Palmer amaranth (*Amaranthus palmeri*) was first discovered in North Dakota in 2018 and has since been discovered in 13 counties. Palmer amaranth was introduced in 2018 and 2019 through various means including cover crop seed and used equipment purchased from other states. A recent infestation was traced to a sunflower processing plant that sold screenings to farmers as cattle feed. Samples found these screenings to contain numerous weeds including pigweeds (*Amaranthus* spp.), velvetleaf (*Abutilon theophrasti*), cocklebur (*Xanthium strumarium*), common lambsquarters (*Chenopodium album*), and grain sorghum (*Sorghum bicolor*). Pigweed seeds were the most common weed seed contaminant of the sunflower screenings, and subsequent sampling revealed over 2800 pigweed seeds per kg of screenings. Seeds were submitted to the National Agricultural Genotyping Center for genetic testing that revealed the seeds to be primarily Palmer amaranth. Three greenhouse experiments were conducted evaluate the presence and prevalence of herbicide resistance in the Palmer amaranth populations found in these screenings. An herbicide mode of action screen was conducted by applied 1x (in parentheses) and 3x ND field rates of glyphosate (1260 g ha^{-1}), imazamox (35 g ha^{-1}), fomesafen (198 g ha^{-1}), atrazine (560 g ha^{-1}), dicamba (560 g ha^{-1}), and 2,4-D (560 g ha^{-1}). Two additional resistance screens were conducted by spraying 112 plants with 1,260 or 35 g ha^{-1} of glyphosate or imazamox, respectively. Leaves from each plant that were tested for glyphosate resistance were genetically tested for markers corresponding to resistance. Results from the herbicide mode of action screen found the population to be resistant to field rates of glyphosate with 55% of tested plants surviving, imazamox with 77% survival, and atrazine with 64% survival. The results from the 112-rep resistance screens found 41% of plants survived glyphosate 21 DAT, 89% of which were genetically identified to have amplification of EPSPS as a resistance mechanism. The remaining 11% that survived had normal copy numbers of EPSPS, indicating another mechanism of glyphosate-resistance is present in the population. Of the plants screened for imazamox resistance, 81% of plants survived 21 DAT. Due to the nature of being introduced through sunflower screenings from a sunflower processing plant, these new Palmer amaranth populations are likely a combination of numerous populations from the US, leading to the highly variable response to herbicides. Further research is needed to evaluate response to atrazine, dicamba, 2,4-D, and other herbicides that are typically used in North Dakota.

Sequential Applications of Metamitron for Control of Palmer Amaranth and Kochia in Sugarbeet. Nevin Lawrence*[1], Andrew R. Kniss[2]; [1]University of Nebraska, Scottsbluff, NE, [2]University of Wyoming, Laramie, WY (125)

There are currently no effective herbicides for managing glyphosate and ALS-resistant kochia (*Bassia scoparia*) and Palmer amaranth (*Amaranthus palmeri*) in sugarbeet. In 2019 the herbicide metamitron was evaluated for herbicide efficacy and crop safety in Scottsbluff, NE and Lingle, WY. At both locations metamitron alone provided control past 4 TL (2.8 kg ai ha^{-1}) and 6TL (5.6 kg ai ha^{-1}) sugarbeet growth stage, while metamitron PRE fb acetochlor POST provided season-long weed control of Palmer amaranth, common lambsquarters (*Chenopodium album*), and redroot pigweed (*Amaranthus retroflexus*). To better understand the metamitron efficacy across a broader rate structure, the utility of applying metamitron in a sequential PRE/POST system, the potential synergy of metamitron and ethofumsate, and the influence of irrigation system (gravity irrigation compared to overhead irrigation) two separate experiments were conducted in 2020. The first experiment evaluated metamitron applied PRE at 1.28, 2.56, 3.84, 5.1 and 6.4 kg ai ha^{-1}, with and without ethofumesate (1.47 kg ai ha^{-1}) as a tank mix partner. This first experiment was conducted on separate gravity and sprinkler irrigated fields in both Powell, WY and Scottsbluff, NE. A second experiment evaluated metamitron applied PRE at 1.46, 3.28, 4.9, and 6.54 kg ai ha^{-1} applied alone, or followed by a second application of 1.46 kg ai ha^{-1} at 2TL or 4TL. The second experiment was only conducted in Scottsbluff. In the first experiment when overhead irrigation was used, at both the Powell and Scottsbluff locations, common lambsquarters, redroot pigweed, and Palmer amaranth control was greater than 90% eight weeks after application when metamitron was applied alone at 4.8 kg ha^{-1}. However, when metamitron was tank mixed with ethofumsate, metamitron applied at 1.8 kg ha^{-1} was adequate for control of all three weed species eight weeks after application. Under gravity irrigation, weed control was poor at the Powell location, and at the Scottsbluff location weed density was insufficient to evaluate control. When kochia was present, metamitron did not provide sufficient control. In the second study, located in Scottsbluff, weed control was highly variable within treatments and between replications making analysis difficult. However, sugarbeet root yield and estimated recoverable sugar did improve when a sequential application of metamitron was made compared to PRE alone, 67 to 75 and 9.5 to 10.8 tons ha^{-1}, respectively. Metamitron does not control kochia. Metamitron efficacy may be negatively impacted when overhead irrigation or adequate moisture is not available at the time of application, ethofumesate greatly improves metamitron efficacy, and sequential application of metamitron do improve sugarbeet yield compared to a single PRE applications. Trials undertaken in 2020 will be repeated in 2021.

Banded Cover Crop Termination to Reduce Negative Impacts on Sugarbeet. Andrew R. Kniss*[1], David A. Claypool[1], Albert T. Adjesiwor[2]; [1]University of Wyoming, Laramie, WY, [2]University of Idaho, Kimberly, ID (126)

A field study was conducted in Sheridan, WY in 2019 to quantify the impact of cover crop-free band width on sugarbeet. Winter wheat was planted approximately three weeks before sugarbeet, then sugarbeet was planted in 76 cm rows perpendicular to the wheat. Immediately after sugarbeet planting, glyphosate was band sprayed directly over the sugarbeet row at widths of 9 cm to 76 cm. The experiment was a RCBD with 6 replicates. Sugarbeet stand was reduced if the cover crop-free band width was less than 23 cm, and sugarbeet biomass was reduced at band widths less than 50 cm.

WSWS PROJECT 4: TEACHING AND TECHNOLOGY TRANSFER

Herbicide Diversity Calculator: Interactive Web App That Estimates the Risk of Herbicide Resistance. Andrew R. Kniss[1], Albert T. Adjesiwor*[2], Nevin Lawrence[3]; [1]University of Wyoming, Laramie, WY, [2]University of Idaho, Kimberly, ID, [3]University of Nebraska, Scottsbluff, NE (061)

Using effective herbicide mixtures is one of the commonly recommended practices for managing herbicide-resistant weeds. However, determining which herbicide combinations will provide effective broad-spectrum weed control at an affordable cost while also providing effective proactive resistance management can be cumbersome. This interactive web application (http://bit.ly/HerbRisk) qualitatively estimates the risk of herbicide-resistant weed evolution based on herbicide programs entered by the user. The model was coded in the R programming language, and a web interface was added using the shiny development environment. The app has a user-friendly interface that allows farmers, agronomists, or researchers to select the crops and herbicide programs they plan to use over a 4-year period, then estimates herbicide resistance risk score for each herbicide site of action chosen. Herbicide efficacy data was estimated from a variety of sources for a single site of action (SOA) and premixed herbicides registered for use in sugarbeet, corn, dry bean, small grains, and soybean. Because the evolution of herbicide resistance is a multi-year process, the model requires users to choose crops and herbicide programs for a 4-year period before it will provide risk estimates. Once herbicides are chosen for all four years, and a weed species is selected, the model calculates herbicide efficacy, cost of control, and an herbicide resistance risk score for each selected herbicide SOA. Risk scores are currently on a scale of 0 to 4. The minimum score of 0 means the herbicide site of action was never used during the 4-year period. Each time an effective SOA is used on the target weed, that SOA is initially given a score of 1; however, this score is reduced if a second effective SOA is applied in the same year. If a SOA is selected each of the four years, and in all four years there was no effective second SOA selected, this would result in the maximum risk score of 4. The risk score for each SOA within a year is reduced by an amount that depends on the efficacy of the second SOA. At this time, the risk scores calculated by the model should be considered qualitative – that is, a risk score value of 0.5 is not necessarily twice as likely to select for resistance as a risk score of 0.25. The model is being updated to include crop rotation restrictions and other grown in the region. The eventual is goal is to provide quantitative risk estimates as well as herbicide and crop rotation recommendations for effective herbicide resistance management.

The International Weed Genomics Consortium: A Resource for Weed Genomics. Sarah Morran*[1], Dana R. MacGregor[2], Eric L. Patterson[3], Joseph S. McElroy[4], Roland S. Beffa[5], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Rothamsted Research, Harpenden, United Kingdom, [3]Michigan State University, East Lansing, MI, [4]Auburn University, Auburn, AL, [5]Bayer AG, CropScience Division, Frankfort / Main, Germany (062)

The International Weed Genomics Consortium (IWGC) is launching in January 2021 and represents the global community of scientists developing genomic tools to advance the understanding and management of weedy plant species. Understanding evolutionary processes in weeds, such as resistance, stress tolerance, and gene flow, requires genomic resources and a trained workforce to analyze and implement innovation with this data. The IWGC is addressing these challenges to develop the critical resources for major weeds through Academia and Industry research and training partnerships. The objectives are to 1) Obtain quality reference genomes for the most important weed species worldwide; 2) Provide user-friendly genome analytical tools and training through web-based databases and resources; and 3) Facilitate inter-disciplinary collaboration and workforce development within this emerging field. Initially six US and nine international universities are committed members. Founding sponsoring members include Bayer CropScience, BASF, Corteva Agriscience, Syngenta, and CropLife International. The USDA Foundation for Food and Agricultural Research is supporting additional sequencing of perennial and invasive weed genomes as well as additional training opportunities. The IWGC will complete more than 10 weed genomes within three years, with Corteva as the sequencing partner and annotation led by Michigan State. The IWGC will provide platinum-standard genome assemblies with corresponding annotations to support the overall goal to use the outcome of weed genomics research for weed management. The IWGC is hosting a weed genomics conference on September 22-24, 2021, in Kansas City, MO, with support from USDA-AFRI. The conference will be hybrid with in-person and virtual options, including hands-on training, keynote speakers, a poster session, and a workshop to prioritize weed genomics research objectives. For more information and to join the IWGC, please visit www.weedgenomics.org.

Assessment of Light Activated Sensor Controlled Spray Technology in Eastern Washington Fallow Systems. Lydia S. Fields*, Ian C. Burke, Rachel J. Zuger, Derek Appel, Ronald Sloot; Washington State University, Pullman, WA (128)

Weed sensing spray technology may improve fallow weed management in Eastern Washington. The Mediterranean climate dictates dryland winter wheat is grown in a two-year rotation with summer fallow to conserve soil moisture. Weed management during the fallow rotation is essential for moisture conservation and has a direct impact on wheat yield potential. Utilizing light activated weed sensing sprayer technology to control weeds during the fallow season may effectively reduce per hectare herbicide application rates, without sacrificing herbicide efficacy. Two studies were conducted to evaluate the potential application of weed sensing spray technology in Eastern Washington. The objective of the first study (Study 1), with five trials repeated over three years, was to evaluate the efficacy of the weed sensing sprayer vs. broadcast sprayer to control target weed species using different herbicide treatments in a single application. The objective of the second study (Study 2), with four trials repeated over two years was to evaluate the economic savings associated with multiple glyphosate applications by the weed sensing sprayer vs. broadcast sprayer over the entire fallow season. Results from Study 1 indicate that there is no difference in efficacy for herbicides applied weed sensing vs. broadcast for the target species, with 3 exceptions for individual herbicides, and that for each herbicide there are economic thresholds dependent on weed density in a field. Results from Study 2 suggest that weed sensing applications can be less expensive than broadcast applications, but cost is dependent on weed density and number of applications throughout a season.

WSWS PROJECT 5: BASIC BIOLOGY AND ECOLOGY

Genetic Mapping of Dicamba Resistance in *Bassia scoparia*. Jacob S. Montgomery*[1], Neeta Soni[2], Sarah Morran[1], Franck E. Dayan[1], Philip Westra[1], Eric L. Patterson[3], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Corteva Agriscience, Indianapolis, IN,[3]Michigan State University, East Lansing, MI (056)

Dicamba usage has increased in recent years due to increased usage in no-till chemical fallow to control glyphosate-resistant weeds and due to the recent introduction of genetically modified crops resistant to dicamba. These increased uses have accelerated evolution of dicamba resistance in weedy species due to increased selection pressures. A dicamba-resistant population of *Bassia scoparia* (M32) from Akron, Colorado was identified in an herbicide resistance survey conducted in 2012, though the mechanism for this resistance remains unknown. Dose response studies confirmed dicamba resistance within M32 (R:S LD50 ratio of 11) of approximately equal magnitude conferred by the previously reported G127N mutation in the IAA16 gene (R:S LD50 ratio of 15). Sanger sequencing of 58 dicamba-resistant M32 plants revealed the absence of the G127N mutation in the IAA16 gene. Populations segregating for dicamba resistance were produced via a bi-parental cross between plants of M32 and a dicamba-sensitive reference population (7710). Approximately 300 plants each from two segregating F3 families were screened with a delimiting rate of dicamba and ratios of alive and dead plants suggest dicamba resistance is likely simply inherited as a single incompletely dominant gene. Future work will include QTL mapping of dicamba resistance within M32 to identify candidate gene(s) involved in a potentially novel mechanism of dicamba resistance.

Utilizing Thermal Time to Assist in Scheduling Management Practices to Control Weedy Rice (*Oryza sativa spontanea*) in California Rice Cropping Systems. Liberty B. Galvin*[1], Whitney Brim-DeForest[2], Kassim Al-Khatib[1]; [1]University of California, Davis, CA, [2]University of California Division of Agriculture and Natural Resources, Yuba City, CA (057)

Weedy rice (*Oryza sativa* f. *spontanea*), a conspecific of cultivated rice (*Oryza sativa*), is difficult to control in California rice cropping systems due to biological characteristics such as competitive growth habit and early maturation, and agronomic constraints including a lack of chemical control options and an absence of herbicide-tolerant varieties. Because of these factors, California weedy rice should ideally be controlled early in the season to reduce infestation rates and minimize yield losses. The purpose of this research is to identify the calendar and thermal timing of emergence of California weedy rice types 1, 2, 3 & 5 under field conditions. This study was conducted in a single field west of UC Davis campus, Davis, CA, in the summer of 2019 and again in 2020. The soil was intentionally infested by one of four weedy rice types, 1, 2, 3, or 5 to simulate a weedy seedbank; 30 dormant seeds of each type were incorporated at random depths within each sampling plot at the start of experimentation in both years. Soil and water temperature were calculated hourly for the 21-day duration of each experiment. Once a seedling emerged from the soil surface, it was removed and burial depth was noted. The majority of seeds (=80%) regardless of type emerged from the top 1 cm in both years. Type 3 had significantly more emergence compared with type 1 in both years; type 2, 5, and 3, as well as types 2, 5, and 1 were not significantly different from one another in either year. Emergence was not observed after 14 DAF in 2019; comparatively, it took 21 DAF in 2020 for emergence to cease. When translating calendar days into thermal time, maximum emergence for all weedy rice types was reached at or near 300°C days for both years. Types 2 and 3 had significantly more total emergence in 2019 compared to 2020. There was roughly 14°C days accumulated per 24-hour period in 2020 and 24°C days per 24-hour period in 2019. The higher rate of heat accumulation in 2019 could account for the greater emergence observed in types 2 and 3, or it could be due to significantly warmer temperatures at the beginning of the experiment in 2019 compared with 2020. This research illustrates the importance of understanding how temperature influences California weedy rice and can be used to time control strategies or planting date of cultivated varieties.

Enhanced Metabolism of 2,4-D in 2,4-D Resistant Palmer Amaranth Population from Kansas. Chandrima Shyam*, Dallas E. Peterson, Mithila Jugulam; Kansas State University, Manhattan, KS (058)

In 2018, a population of Palmer amaranth (KCTR) was suspected to have evolved resistance to 2,4-D, a widely used auxinic herbicide. Previous studies confirmed a 9-14 fold resistance to 2,4-D in KCTR. Further 2,4-D absorption and translocation studies indicated no difference in [^{14}C] 2,4-D absorption, while ~10% less [^{14}C] 2,4-D was translocated in KCTR compared to two susceptible populations (S1 and S2). In this study, we hypothesized that enhanced metabolism may bestow resistance to 2,4-D in KCTR. The objectives of this study were to i) investigate the rate of [^{14}C] 2,4-D metabolism in KCTR Palmer amaranth compared to S1, S2, and wheat (naturally tolerant to 2,4-D) and ii) determine the role of cytochrome P450 (P450) enzymes in metabolizing 2,4-D using P450-inhibitor (malathion). The results suggest KCTR Palmer amaranth rapidly metabolizes 2,4- compared to S1 and S2. Further, based on the [^{14}C] 2,4-D retention time, both KCTR and wheat generated similar polar [^{14}C] 2,4-D metabolites. Nonetheless, ~70% of [^{14}C] 2,4-D was metabolized in wheat, compared to only 30% in KCTR Palmer amaranth. The results of malathion plus 2,4-D dose-response assay indicated that application of malathion prior to 2,4-D treatment resulted in ~60% reduction in biomass of KCTR. Overall, the data from this research suggest that enhanced metabolism, potentially mediated by P450 enzyme activity is the primary mechanism imparting 2,4-D resistance in KCTR Palmer amaranth.

Isolation of Acetyl-CoA Carboxylase to Compare Specific Activity and Enzyme-Level Quizalofop Resistance of CoAXium® and Non-CoAXium® Wheat. Raven A. Bough*, Franck E. Dayan, Todd A. Gaines; Colorado State University, Fort Collins, CO (059)

The quizalofop tolerance trait in CoAXium wheat is conferred by a homozygous point mutation resulting in an alanine to valine amino acid substitution in two of three acetyl-CoA carboxylase (ACCase) homoeolog enzymes. The substitution causes a slight conformational change that provides resistance to quizalofop herbicide. To determine if the conformational change affects specific activity and to compare dose-response resistance, ACCase was extracted from susceptible and quizalofop-tolerant wheat. Tissue was collected from susceptible varieties as well as tolerant varieties with varying numbers of resistant homoeologs. Enzyme was precipitated and refined from filtered homogenate using a combination of ammonium sulfate saturation, centrifugation, and desalting. For specific activity assays, fresh ACCase extracts were immediately incubated in a buffered solution containing ATP and ^{14}C-labeled bicarbonate substrate. Quizalofop treatments were provided during this step for dose-response assays. The rate-limiting substrate, acetyl-CoA, was added to initiate the formation of malonyl-CoA product. Samples were quenched using concentrated hydrochloric acid, prompting unused ^{14}C-bicarbonate to release as gaseous carbon dioxide, whereas ^{14}C incorporated into malonyl-CoA by ACCase remained in solution. Radioactivity was measured using a liquid scintillation analyzer. An ANOVA followed by multiple comparison tests indicated that there were no significant differences (a=0.05, n=3) in specific activity between ACCase extracts. Three parameter log-logistic models were fit to dose-response measurements (n=24) for extracts from two susceptible and one tolerant wheat variety. Dose estimates that achieve 50% inhibition were compared using Student's t-tests (a=0.05), where the tolerant variety was 145 times significantly more resistant than susceptible varieties.

Using a New Reference Genome to Investigate the Genetic Architecture of Flowering Time Traits in *Bromus tectorum*. Ian C. Burke[1], Samuel R. Revolinski*[1], Craig Coleman[2], Jeff Maughan[2]; [1]Washington State University, Pullman, WA, [2]BYU, Provo, UT (060)

Paper withdrawn

Integrating Grazing, Herbicide, and Seeding to Diversify Crested Wheatgrass Monocultures. Peter T. Bugoni*; Montana State University, Bozeman, MT (146)

To compete with weed species and increase livestock forage crested wheatgrasses (Agropyron cristatum [L.] Gaertn. and A. desertorum [Fisch. ex Link] Schult.) was seeded across western rangelands. Many of these historic plantings now persist as near-monotypic stands, and active diversification efforts are necessary to increase plant species' diversity and improve wildlife habitat. However, past diversification efforts have shown limited success in suppressing crested wheatgrass and establishing native species. We designed a 5-year study at two sites in Montana integrating herbicide treatments to control crested wheatgrass with seeding treatments to increase native species. Our three herbicide treatments were a low (96 oz/acre) and a high rate (192 oz/acre) of glyphosate and a non-sprayed control. Our two seeding patterns were perpendicular (native grass species and native forb species seeded separately in differing rows) and straight (both grasses and forbs seeded together in similar rows). Prior to applying these treatments, the sites were grazed intensively for two-years, with grazing occurring when crested wheatgrass phenology was most vulnerable. First-year results showed the high glyphosate rate suppressed crested wheatgrass 5-10% more than the low rate, and both chemical treatments suppressed crested wheatgrass 40-50% more than grazing alone. Seeding grasses and forbs separately (perpendicular) did not result in density differences at either site. Seeded grass density was 2-6 plants/m^2 higher when plots were treated with glyphosate as compared to control plots. We will sample sites for two more years. While preliminary, we conclude glyphosate effectively reduced crested wheatgrass density, forb establishment improved when glyphosate is applied prior to planting, and it may be too early to detect differences in seeding patterns.

Exploring the Constituitive Shade Avoidance Response in *Beta vulgaris*. Joe Ballenger*, David A. Claypool, Andrew R. Kniss; University of Wyoming, Laramie, WY (147)

Although yield loss due to weed competition is among the most important problems in agriculture, specific factors responsible for yield loss due to competition from weeds has remained unclear. To determine the relative contribution of resource competition and shade avoidance response to yield loss, we used a factorial arrangement of three competition treatments and three irrigation levels. We grew beets in 19 liter buckets and imposed three competition treatments: no competition, shade avoidance only, and shade avoidance plus root interaction. The shade avoidance treatment was surrounded by Kentucky bluegrass (*Poa pratiensis*) using a barrier to prevent root interaction. To allow root interaction, we perforated the barrier. Irrigation levels included fully irrigated to 100% sugarbeet evapotranspiration (ET), moderate water stress (80% ET) and severe water stress (60% ET). Under fully irrigated conditions, shade avoidance reduced leaf number 15% (P=0.001) but did not significantly reduce leaf area (P=0.85) compared to the no competition treatment. Under severe drought stress, similar effects were observed on leaf number (15% reduction, P=0.002) and leaf area (P=0.96). Root biomass production was reduced 19% by shade avoidance under fully irrigated conditions (P=0.03), but shade avoidance did not reduce root biomass production under severe drought stress compared to no competition (P=0.99). In contrast to many plants, sugar beets produce smaller and shorter plants under shade avoidance signals (low R:FR light). Sugarbeets were able to maintain biomass under severe water stress while undergoing shade avoidance. These results may thus provide an explanation to the apparently paradoxical *B. vulgaris* shade avoidance response.

Russian Thistle Genomics to Help Understand "Tumbleweeds". Philip Westra*[1], Eric L. Patterson[2], Todd A. Gaines[1], Jacob S. Montgomery[1], Kevin Dorn[3]; [1]Colorado State University, Fort Collins, CO, [2]Michigan State University, East Lansing, MI, [3]USDA Sugarbeet Unit, Fort Collins, CO (148)

Abstract not available

SYMPOSIUM 1: Annual Invasive Grass Management

"Invasive Annual Grass Challenge: Stepping it Down for a Path Forward". Lindy Garner*; Invasive Species Coordinator, Sagebrush Ecosystem Team USFWS Upper Colorado Basin (IR7) & Missouri River Basin (IR5) Interior Regions, Great Falls, MT (001)

In 2020 alone, almost 1.4 million acres burned in sagebrush rangelands across the Western US, often fueled by invasive annual grasses, such as cheatgrass, medusahead and ventenata. Fires become more frequent and intense when these ecosystem disruptors are present, and they threaten local economies, wildlife, agricultural productivity, recreational opportunities, and human safety. We can protect intact and vulnerable sagebrush communities from loss to the invasive grass/wildfire cycle by coming together to focus on the core concepts and model of 1) "Defend the Core" by strategically using early detection rapid response efforts and strategies to prevent and eradicate early infestations, 2) "Grow the Core" with aggressive invasive management and restoration to disrupt new invasions and prevent conversion into a more heavily invaded state, and 3) Mitigate heavily invaded areas with fuels management in priority areas to prevent wildfires. Federal, state and private lands are all significantly affected by invasives and fire and require critical collaboration for a path forward. Shared decision space empowers all partners to prioritize at multiple levels and identify science-based methods resulting in landscape partnerships that target cost-effective management. Working together from regional to local scale across the landscape managing invasive annual grasses prevents tipping the balance of native communities to degraded areas and future wildland fire risk that helps break the fire-invasion cycle in priority areas.

Bio-pesticides for Exotic Annual Grasses: Review of Evidence for Effectiveness of Weed-suppressive Bacteria. Matthew Germino*[1], Brynne E. Lazarus[2]; [1]Supervisory Research Ecologist U.S. Geological Survey, Boise, ID, [2]Botanist USGS Forest and Rangeland Ecosystem Science Center, Boise, ID (002)

Exotic-annual grasses (EAGs) such as cheatgrass are among the most severe agents of ecosystem degradation in western rangelands, and tools for reducing their abundance are needed to protect or restore threatened or impacted plant communities. Weed-suppressive bacteria (WSB), specifically strains of Pseudomonas fluorescens, have been proposed to selectively inhibit seedling growth and survival of EAGs following their application to soil surfaces and are thus considered a bio-pesticide or bio-herbicide. WSB have been available in various forms to land managers for over 5 years, and many applications over large areas have been made to date. Whereas several published studies detected inhibition of EAGs as well as native grasses in petri dish cultures, there is mixed and generally negative field-based evidence for WSB effectiveness. A current absence of the molecular markers needed to monitor WSB abundances in field soils is a severe impediment to understanding WSB effects. Several field trials are underway to determine the effectiveness of the most recently EPA-approved WSB agent, strain ACK55 that is sold as "Battalion Pro", with and without manipulation of organic matter, co-application of chemical herbicides, and seedings of native perennials.

Managing Rangelands for Outcomes. John F. Ruhs*; Idaho State Director Bureau of Land Management, Boise, ID (003)

Abstract not available

Changing the Tide by Targeting the Seed Bank and Preserving In-tact Perennial Systems. Scott J. Nissen*; Colorado State University, Fort Collins, CO (004)

Downy brome (*Bromus tectorum*) is a winter annual grass that is the most widespread invasive species in the western US, covering an estimated 54 million acres, with a projected 14% annual spread rate. With continued spread of downy brome and new invaders like medusahead (*Taeniatherum caput-medusae*) and ventenata (*Ventenata dubia*), rangeland managers have been needing a tool that provides longevity in control while not negatively impacting the desirable plant communities. The concept and use pattern for Rejuvra (indaziflam) on rangeland resulted from research conducted by CSU weed scientists beginning in 2010 near Rifle, CO. The results were extremely promising, especially when compared to other products that were considered industry standards, and during this time land managers were starting to lose hope that we would ever get a handle on downy brome. At the same time this research was being conducted, another parallel research track was initiated to determine the soil seed-bank life of downy brome. Since the initial research trials in CO, now over 18 Universities, six federal agencies, and many counties/municipalities have expanded the research and operational treatment of this new tool. These research and operational collaborations have determined that Rejuvra controls all the major invasive winter annual grasses and certain noxious broadleaf weeds (from seed), and for the first time provides the opportunity to target in-tact perennial plant communities at risk of future decline, by targeting the invasive grass soil seed bank.

Putting it All Together: Putting Tools into Landscape Context. Brian Mealor*; University of Wyoming, Laramie, WY (005)

Invasive annual grasses pose significant management challenges in the rangeland of the western U.S. We have steadily increased our knowledge of management tools and tactics, and we are now beginning to approach annual grass management from longer-term, landscape-scale perspectives. Developing effective management programs in complex socio-ecological landscapes calls for the prioritization of efforts based on multiple criteria tied directly to management goals. One might argue that a successful invasive annual grass management program uses the right tool in the right place at the right time for a sufficient duration to move the vegetation toward clearly stated management goals. New landscape-scale prioritization tools facilitate such strategic efforts, but more is needed moving forward. Linking science to practice – long a hallmark of weed science – need to have continual emphasis moving forward.

Sublette County Invasive Species Taskforce: Countywide Cheatgrass Program. Julie A. Kraft*; Sublette County Weed and Pest, Pinedale, WY (006)

The Sublette County Invasive Species Taskforce works with multiple partners and collaborators to implement a county-wide cheatgrass strategy. Working across boundaries at the watershed level we use science, monitoring and collaboration to make dynamic management decisions to manage downy brome infestations over 3.2 million acres. Using the best tools available at the time this taskforce has treated tens of thousands of acres to limit the soil seed bank and decrease damage to the intact rangelands of Sublette County. Partnerships are the key to our success.

Ventenata and Medusahead in Northeast Wyoming. Jaycie N. Arndt*, Brian A. Mealor; University of Wyoming, Sheridan, WY (007)

Ventenata (*Ventenata dubia* (Leers) Coss.) and medusahead (*Taeniatherum caput-medusae* (L) Nevski.) were identified in Sheridan County, Wyoming in the summer of 2016. Shortly after, the Northeast Wyoming Invasive Grasses Working Group (NEWIGWG) was established as a multi-stakeholder group that implemented an Early Detection Rapid Response (EDRR) approach for managing both annual invasive grasses. Contribution in the group has since expanded to include input from private landowners, NGO's, and local, state, and federal agencies across multiple counties in Wyoming as well as coordination with stakeholders in neighboring states. The goals of the group are to prevent further spread of invasion, raise community awareness, better understand the population ecology of both species, implement treatments to control current self-sustaining populations, and monitor and adapt treatments. Initial efforts included surveying 42,600 acres of land in Sheridan County in 2017. Efforts were taken to build a containment strategy for ventenata populations from spreading outside a three-county area in northeast Wyoming. The objective for medusahead control was based on eradication of the smaller population located in only Sheridan County. As of fall 2020, 59,000 acres have been treated with indaziflam, and 7000 acres have been monitored post-treatment. The group continues to concentrate on new treatment areas, best-management practices, data collection, monitoring, mapping, and effective retreatment.

Invasive Annual Grass Management in Utah - Ventanata. Corey V. Ransom*; Utah State University, Logan, UT (008)

Invasive annual grasses are of great concern in Utah. While downy and Japanese brome are widespread throughout Utah, Medusahead is still limited to five or six of the 29 Counties. More recently discovered, Ventenata is currently found in Cache and Box Elder Counties in Northern Utah. Since the early 1990's research has been undertaken to identify successful strategies for managing invasive annual grasses. Early efforts were hampered due to limited herbicide options. In addition to research efforts, growers have sought to organize medusahead management efforts. In 2000, a group of landowners joined together to form a CRM focused on managing medusahead. In the mid 2000's funding for a Weed Prevention Area provided resources to hire a coordinator to organize treatment efforts. Research at Utah State University has sought to improve herbicide effectiveness by evaluating herbicide rates and application timings, spray volume and patterns, and herbicide combinations. USU research shows that in Utah applying Plateau in the spring is more effective than early or late fall and provides enough residual to inhibit germination 6 months later. Whereas Plateau applied in August or September is depleted when the next cohort of annual grasses germinate the following year (12 months later). More recent research has demonstrated that annual grass control can be extended 4 years or more with applications of Rejuvra. This product is the first to offer long-term management of annual grass germination from the soil seedbank. Funding through the Utah Department of Agriculture and Food Invasive Species Mitigation Grant program, started in 2013, has provided resources to address critical weed issues as well as support long-term management systems research. Ventenata was first recorded in Northern Utah in 2011 and after managers became familiar with this species, numerous infestations have been identified. At this time, there are believed to be fewer than 1,000 acres infested with ventenata. Research trials investigating ventenata control were initiated in 2017 and demonstrated that many of the treatments used to manage medusahead can also control ventenata. A ventenata control project was also initiated in 2017 and treatments were implemented in 2018. This project involved the County Weed Supervisor, several UDAF personnel, USU Extension, and others. Because the site was highly degraded with little perennial vegetation, a restoration approach was outlined. Plateau was applied in May of 2018. A dryland seed mix was planted in the spring of 2019 and was successful due to above average precipitation. In spring of 2020 it was determined that seedlings were well rooted and a light grazing with sheep was used to reduce prickly lettuce competition. Rejuvra was applied in August 2020 to protect the new seedings from re-invasion by ventenata and downy brome. Combined efforts informed by local research are proving to be effective for managing ventenata and other invasive annual grasses in Utah.

Colorado Front Range Invasive Annual Grass Management Successes. Steve Sauer*; Boulder County Open Space, Longmont, CO (009)

Invasive winter annual grasses such as cheatgrass (*Bromus tectorum*) continue to negatively impact the Colorado Front Range. Impacts include displacement of species diversity, displacement of critical wildlife and pollinator habitat, and a drastic increase in fine fuels associated with wildfire. Since beginning in 2015 in collaboration with Colorado State University, Boulder County Open Space has treated operationally over 3,500 acres of open space with indaziflam (Rejuvra), resulting in effective long-term cheatgrass control and restoration of the desirable perennial species found at these sites. One concern of land managers, ecologists, and wildlife biologists in Boulder County and neighboring jurisdictions is the ever-increasing threat of cheatgrass, the possible permanent displacement of these in-tact ecosystems, and wildfire risk. There has now been a joint effort with several counties and municipalities along the Colorado Front Range to tackle cheatgrass head on and expand cross boundary restoration of cheatgrass invaded rangeland and open space.

Collaborative Invasive Grass Projects from the Federal Level in Colorado and Nevada. William Kutosky*; USFWS, Partners for Fish and Wildlife Service, Elko, NV (010)

Invasive winter annual grasses across the West pose complex management challenges and are one of the leading drivers in habitat loss. Managing invasive winter annual grasses through a collaborative approach in Colorado and Nevada has provided land managers an opportunity to learn from one another and generate new ideas for achieving landscape scale restoration. Imazapic and "indaziflam (Rejuvra)" are two pre-emergent herbicides that have proven successful in managing for invasive winter annual grasses. The U.S. Fish and Wildlife Service (USFWS), Bayer and Colorado State University partnered to install test plots of indaziflam and imazapic at the Rocky Mountain Arsenal National Wildlife Refuge to compare the efficacy of these two herbicides across multiple habitat types in demonstration plots that were intentionally established in sites accessible to the public. Lessons learned from this partnership and herbicide trials are proving beneficial in contributing to collaborative efforts that are on-going in northeastern Nevada to achieve landscape scale restoration. These collaborative efforts include a local area working group established in 2020 in Elko County, NV that includes state, county, and federal agencies working together to identify, prioritize and treat medusahead and ventenata infestations across all landownership boundaries and the USFWS Nevada Invasive Treatment and Restoration Initiative that is funding research to compare imazapic and indaziflam treatments in sagebrush grasslands that are still supporting native grasses, forbs, and sagebrush, but are also being invaded by cheatgrass.

SYMPOSIUM 2: Are Herbicide-Resistant Crops the Solution to Herbicide-Resistant Weeds?

How Herbicide-resistant Crops Can Contribute to Integrated Weed Management. Hugh J. Beckie*; University of Western Australia, Perth, Australia (011)

Herbicide-resistant (HR) cultivars of agronomic crops such as soybean, corn, cotton, and canola have significantly impacted weed management practices over the past 25 years. Cultivars with single-HR traits were initially introduced. Today, stacked-trait cultivars are increasingly being introduced and adopted by growers primarily to manage increasing incidence and complexity of herbicide-resistant weeds. HR crops can potentially contribute directly or indirectly to integrated weed management (IWM) by: 1) reducing herbicide-use intensity vs. non-HR cultivars; 2) improving weed control with no crop injury over a wide application window; 3) allowing different herbicide sites of action (SOA) in cropping systems to diversity herbicide SOA usage, and control existing HR weeds or troublesome weed species; 4) facilitating conservation tillage and enhance crop growth and weed competitiveness in water-limited environments; 5) allowing greater flexibility in planting dates that may optimize crop yield and weed suppression potential; and 6) utilizing better crop germplasm, which aids crop health and competitiveness. In arid environments of western North America or Western Australia (WA), the main HR crops are wheat, barley, canola and lentil. In WA, imidazolinone (IMI)-HR barley and triazine-HR canola are widely adopted mainly because of their respective HR traits to control troublesome weed species as well as facilitate herbicide SOA diversity, early seeding for greatest yield potential, provide a break crop, etc. Overall, they have a moderate to high beneficial impact on IWM although there is little data on relative herbicide usage. However, HR barley contributes to group 2 selection pressure for resistance and usually requires another herbicide SOA for annual ryegrass (*Lolium rigidum*) control or other species with widespread group 2 resistance. Conversely, IMI-HR wheat has minimal impact on IWM due to low adoption. Further progress is needed to reduce the gap between actual and potential HR crop contribution to IWM.

Herbicide Tolerance Technologies: Past, Present, Future. Roger E. Gast*, Terry Wright; Corteva Agriscience, Indianapolis, IN (012)

In 1996, glyphosate-tolerant crops (Roundup Ready®) revolutionized selective weed control in broadacre cropping systems. Numerous herbicide tolerant crop (HTC) technologies have been developed using transgenic and non-transgenic techniques with the purpose of improving weed management systems. The key benefit of HTC systems is to increase the spectrum and robustness of weed control by employing herbicide active ingredients that do not already have a natural tolerance to a crop. Additional benefits include simplifying herbicide systems, improving soil conservation through reduced tillage, and the introduction of new or underexploited MOA into a cropping system. Many HTCs are created through genetic modification by introducing genes to express an insensitive form of the target site of action (SOA) or herbicide-metabolizing enzymes. Non-transgenic approaches include chemical or radiation mutagenesis, somaclonal selection, or wild species selection/introgression, to create or select insensitive for insensitive SOA proteins in crops. Initially companies developed single trait systems in crops, for example glyphosate-tolerant soybean, corn, cotton, etc. The current industry trend is development of stacked trait systems of two or more tolerance genes to employ multiple MOA herbicide active ingredients to address increasing levels of herbicide resistance. Future approaches may include introduction of new herbicide MOAs or new chemotype herbicides and associated tolerance traits able to control today's resistant weed biotypes. The rapid increase in genomics technology may even allow for parallel discovery of herbicides and transgenic tolerance traits, or perhaps even non-transgenic approaches. Due to the high cost and time of developing both herbicides and traits, and public acceptance of transgenic crops, typically only major commodity crops are targeted for transgenic HTC technology. Good proactive stewardship is required protect the durability of HTC technologies. Education programs that include proper use and stewardship are essential. HTC systems should be part of an overall integrated approach towards effective and sustainable weed management, including an achievable resistance management plan and execution discipline complementing the HTC technology. Properly employed HTC systems can provide additional tools for weed resistance management and sustainable weed control.

Herbicide Resistant Crops: Friend or Foe in the Canadian Prairies? Breanne D. Tidemann*[1], Eric N. Johnson[2], Robert Gulden[3]; [1]Agriculture and Agri-Food Canada, Lacombe, AB, Canada, [2]University of Saskatchewan, Saskatoon, SK, Canada, [3]University of Manitoba, Winnipeg, MB, Canada (013)

The Canadian Prairies are diverse in terms of precipitation, soil type and cropping systems. The most commonly grown herbicide resistant (HR) crops in the Prairies would be canola in all three provinces, with the additions of lentil in Saskatchewan, and soybean in Manitoba. Canola varieties include glyphosate or glufosinate resistant cultivars, soybean is primarily glyphosate resistant, and lentil are imidazolinone resistant varieties. Of the HR crops, there are few conventional or non-HR varieties grown. For example, HR canola accounts for 99% of canola acres. Glyphosate resistant weeds are limited in western Canada, likely due to the availability of other HR canola varieties, and limited glyphosate resistance in the overall cropping rotation. HR crops have allowed us to manage difficult to control weeds or expand management options, with limited increased selection for herbicide resistance. However, other HR crops such as IMI resistant lentils, significantly increased selection for acetolactate synthase inhibitor resistant weeds. There has also been documented cases of transgene movement from HR crops resulting in stacked HR volunteer species, as well as movement to weedy relatives. There have been positives and negatives in the Canadian Prairie experience with HR crops. Future HR crops and traits need to be carefully evaluated for their potential positive and negative impacts before introduction to the cropping systems.

PNW Herbicide Resistant Crops: Any Role in Resistance Management? Carol Mallory-Smith*; Oregon State University, Corvallis, OR (014)

The Pacific Northwest (PNW) region (Idaho, Oregon, and Washington) has extremely diverse cropping systems. Herbicide-resistant crops are grown in the Pacific Northwest including resistance to herbicides in Groups 1, 2, 4, 9, and 10. This number of options appears to provide opportunity for rotating modes of action within cropping systems to manage resistant weeds. However, in reality the trait/crop combinations restrict their use to limited areas. For example, Roundup Ready glyphosate-resistant (Group 9) sugar beets require irrigation and Clearfield imazamox-resistant wheat (Group 2) production is limited in some areas because of plant-back restrictions for rotational crops. Most of the corn, field or sweet, is grown under irrigation; processors, for the most part, do not accept genetically engineered corn. Although theoretically possible to use herbicide resistant crops to manage herbicide resistant weeds, in reality the crops are grown to manage weeds within a crop and not used in a way that prevents or delays resistance. In fact, the overreliance on glyphosate in Roundup Ready sugar beets selected glyphosate-resistant kochia. It is important to remember that the introduction of a herbicide resistant crop into the PNW is no different from introduction of a selective herbicide into the system. Some herbicides are more effective than others, have fewer concerns from a residual standpoint, or fit better into a cropping system. However, the trait/herbicide combinations and their deployment have not reduced the number of resistant species evolving nor decreased the number of multiple-resistant weed species. In the Pacific Northwest, weeds with resistance are already present in most of the cropping systems so the current resistant crops do not provide any new options.

Role of Herbicide-Resistant Crops for Controlling Herbicide-Resistant Weeds in the Great Plains. Vipan Kumar*, Phillip W. Stahlman; Kansas State University, Hays, KS (015)

The use of herbicides and herbicide-resistant (HR) crops (especially glyphosate-resistant) have allowed to reduce or eliminate tillage for weed management, thereby benefitting soil and water conservation in the semi-arid U.S. Great Plains. The widespread adoption of HR crop technologies has provided a greater flexibility to growers and land managers for controlling weed populations. Horseweed, kochia, Palmer amaranth, Russian thistle, downy brome, foxtails (green and yellow), wild oats, feral rye and Persian darnel are some of the major broadleaf and grass weed species in the region. Herbicide resistance in these weed species have primarily been evolved in summer fallow phase of predominant crop rotations (2 or 3-yrs) where producers rely heavily on PRE and POST herbicides for weed control. The adoption of HR crop technologies such as Roundup Ready® sugarbeet, corn, soybean or cotton has helped producers to control ALS- and PS II inhibitor-resistant weed biotypes over the last two decades. Due to repeated use of glyphosate for weed control in fallow, prior to crop seeding, in-crop and post crop harvest situations, the widespread resistance to glyphosate in kochia, horseweed, Palmer amaranth, and Russian thistle has also been documented in the region. However, recent commercialization of new generations of stacked trait technologies, including Roundup Ready Xtend®, Enlist®, and Liberty Link® have allowed producers to use multiple herbicide site of action for controlling glyphosate-resistant weed biotypes. Similarly, the recent commercialization of CoAXium™ wheat production system has allowed growers to use POST applications of quizalofop (ACCase inhibitor) for control of ALS-resistant grass weeds, including downy brome, Italian ryegrass, jointed goat grass, and feral rye. Three HR technologies viz., Inzen™, iGrowth™, and Double

Team™ in grain sorghum are on verge of commercialization that will allow producers to use over-the-top (POST) applications of nicosulfuron, imazamox, and quizalofop for grass weed control.

SYMPOSIUM 3: Updates from Weed Biocontrol-An Unsung Component of Integrated Weed Management on Land and in Water

Biological Control of Invasive Weeds: Ensuring Safety Through the Regulatory Process. Bob Pfannenstiel*; USDA- APHIS- PPQ, Riverdale, MD (131)

Abstract not available

Western Weed Biocontrol Collaboration: Using Low Tech Tools to Pool Resources and Amplify Understanding and Impact. Carol Randall*; USDA Forest Service, Medimont, ID (132)

Classical weed biocontrol is an underutilized tactic in integrated weed management strategies, often overlooked by land managers working to control invasive plant infestations. In this talk I will introduce classical weed biological control (biocontrol), explain how it works, and describe the management scenarios where biocontrol is likely to be the best control tactic to deploy to manage invasive plants. I will also describe some of the challenges faced by weed biocontrol researchers and practitioners. In the second half of the presentation I will describe how the community of weed biocontrol regulators, researchers, and practitioners in the West coordinate activities and use standard methods and user-friendly technology to monitor, map, evaluate, and report biocontrol success thereby increasing the availability and impact of weed biocontrol efforts. Finally, I will discuss how weed biocontrol practitioners share information amongst themselves and and strive to increase land manager's understanding and implementation of weed biological control. I will conclude with the important role that land managers can play in the future development of weed biocontrol programs.

Monitoring Weed Biocontrol with the Standardized Impact Monitoring Protocol (SIMP). Joseph Milan*; Bureau of Land Management, Boise, ID (133)

Post-release monitoring of biological control is a crucial component to determine biocontrol agent establishment and the impact on the target invasive plant and subsequent plant community response. Commonly, the initial releases of a biological control agent involve a specialized monitoring protocol conducted by the implementation entity responsible for the initial releases. As biological control agents become established at multiple locations, the time-consuming monitoring protocol developed for that specific biological control agent and personnel to conduct the monitoring become scarce. As such, a group of biological control practitioners from Idaho, USA developed a regional, multi-system, interagency post-release assessment program – the 'Standard Impact Monitoring Protocol' (SIMP). SIMP was developed to be citizen-science-friendly and statistically sound with regard to data analysis. SIMP is used to document the change in vegetation cover, target weed density and biological control agent abundance over time. This provides biological control implementation specialists and land managers with a tool to assess the relative impact of the biological control agent and the corresponding change in vegetation after a biological control agent release. Beginning in 2017, a smart phone application was created to collect SIMP data and georeferenced pictures of the monitoring sites. This approach aims to eliminate hard copy data sheets and reliance on old technology that requires significant post-process editing. This, in turn, will make SIMP more user-friendly and accessible to anyone with a smart phone. Included in this presentation is a brief overview of the capabilities of SIMP's online tools and what can be done with the data.

New Online Weed Biocontrol Tools iBiocontrol, SIMP Survey 1 2 3, SIIPA, Apps. Chuck Bargeron*; University of Georgia, Tifton, GA (134)

iBiocontrol is an iOS application, Android application, and website that brings the power of EDDMapS for Biocontrol to the on-the-ground land managers. Data collection is completed electronically and in real-time from the handheld device. When wireless connectivity is unavailable, information is stored on the device until cellular or WiFi connectivity is available. iBiocontrol includes a complete field guide of agents and their host plants using existing USDA Forest Service publications and images in the Bugwood Image Database System. This allows for a full library of information to be stored on a device that will easily fit in your pocket (iPhone/iPod Touch/Android) or backpack (iPad). The Standardized Impact Monitoring Protocol (SIMP) has been converted into a Survey 123 smartphone application for more advanced users, and the data is available on the iBiocontrol website. The iBiocontrol web portal provides access to the World Catalogue of Biological Control Agents, and Their Target Weeds, the Proceedings of International Symposia on Biological Control of Weeds, Biocontrol in Your Backyard – a Youth Biocontrol Education Program, and various publications focused on the biological control of weeds. iBiocontrol is a collaborative effort of The University of Georgia, MIA Consulting, University of Idaho, and the USDA Forest Service.

The Knotweed Psyllid: A New Tool to Combat Knotweeds in Riparian Zones. Joel Price*[1], Fritzi Grevstad[2]; [1]Oregon Department of Agriculture, Salem, OR, [2]Oregon State University, Corvallis, OR (135)

Invasive knotweeds are large perennial herbs in the Polygonaceae that are native to Asia and invasive in North America. They include Japanese knotweed (*Reynoutria japonica* Houtt.), Sakhalin knotweed (*R. sachalinensis* [F. Schmidt] Nakai), and Bohemian knotweed (*R.* x *bohemica* Chrtek & Chrtkov). Widespread throughout the continent and difficult to control by mechanical or chemical methods, these plants are good targets for classical biological control. We reared lab colonies and conducted the first field releases of the psyllid *Aphalara itadori* Shinji from Japan as a biological control agent in the United States. We released, in Oregon, over 10 k adult psyllids across 8 sites in May and June of 2020. Host plants were half of their eventual height at time of release (x = 2.17 m). Adult psyllids oviposited nearly 350 eggs per caged stem. The first generation of field grown adult psyllids peaked at around 600 dd. Lab populations were capable of halting knotweed plant growth resulting in host plant mortality. However, field populations differed markedly in their reproduction once sleeve-cages were removed. Open field counts of adults declined throughout the season (May = 2.3 per count, June = 0.5, July = 0.2, August = 0.0). Adult offspring from the released psyllids were observed at five of the eight release sites. We observed an abundance of predatory mites searching knotweed leaves, likely limiting egg survival. We conclude that *A. itadori* initial releases diminished rapidly post-release. Future methods for release should focus on predator satiation with larger release sizes or escaping predation in time with early spring releases when less predators are likely to have emerged from overwintering.

What Seven Sequential Years of Spring Dry Ground Applications of Imazapyr and Imazamox to Deplete the Rhizomes of Flowering Rush Has Taught Us About the Need to Continue Biocontrol Development for Flowering Rush. Peter M. Rice*[1], Virgil Dupuis[2], Ian McRyhew[2], Alvin Mitchell[2]; [1]Peter M Rice Consulting, Missoula, MT, [2]Salish Kootenai College, Pablo, MT (136)

Flathead Lake is at low pool drawdown in late winter through May. This seasonal drawdown regimen provides a dry ground treatment window for soil active herbicide uptake via roots. Two herbicides: Clearcast at 0.75 or 1.0 lbs ae/A depending on the year and Habitat 1.5 lbs ae/A, both with 2 qt/ac MSO, were applied as "dry ground" treatments in May. Treatments were repeated for seven years (2014-2020). The long-term goal was to reduce the regrowth potential from the rhizomes. After six years Clearcast plots still had 46,538 rhizome leaf initials per acre in early spring 2020 before the seventh spray treatments were made. This density of emergent leaf tips after the first six Clearcast treatments would be sufficient to reestablish a dense infestation in one summer regrowth season without re-spraying. Habitat was consistently more efficacious than Clearcast. Canopy cover control during first six summers after spring spraying Habitat ranged from 95 to 100%. This level of single summer-long top growth control from Habitat was commercially acceptable to lakeshore owners of small areas. Clearcast was less efficacious with summer topgrowth control ranging from 62 to 86% over the first six summers. In the summer of 2020 after the seven treatments 100% topgrowth control was finally obtained by both herbicides. Rhizome weights and density were also reduced by both herbicides. This long-term herbicide effort confirms the necessity of developing biocontrols for suppression of flowering rush economically for numerous small infestations and at watershed scale infestations.

Prospects for Classical Weed Biocontrol to Address Expanding Populations of Flowering Rush. Jennifer Andreas*; Washington State University, Puyallup, WA (137)

Flowering rush (*Butomus umbellatus*) is a perennial aquatic plant of European origin that was introduced to North America as an ornamental over 100 years ago. Biological control of this plant is very promising, because *Butomus umbellatus* is the only species in the family Butomaceae which increases the likelihood of finding host-specific biological control agents. We have currently prioritized three candidate agents. The weevil *Bagous nodulosus* was tested for oviposition (egg-laying) on 45 test plant species and eggs were found only once on one nontarget species. Larval no-choice establishment tests are also confirming that the weevil is highly host-specific. In impact experiments, adult feeding reduced above-ground biomass of flowering rush by 33%, and below-ground biomass was decreased by 50% on plants exposed to adults. We are currently preparing the the petition for field release and plan to submit it in spring 2021. The agromyzid fly *Phytoliriomyza ornata* is another promising agent that can cause plants to wilt after only three days exposure to a single female. Host-specificity tests are underway. Finally, the white smut *Doassansia niesslii* is being studied. The overwintering state of the smut infests plants under water, which will be very advantageous for completely submerged infestations of flowering rush. However, the strains found so far in Germany and France only attack a rare genotype of flowering rush in Canada. Therefore, we need to search for strains infesting the most common genotypes in North America. Identifying the origin of the invasive North American populations of flowering rush is expected to help.

Where We Stand After 20 Years of Tamarisk Biological Control. Dan Bean*; Colorado Department of Agriculture, Palisade, CO (138)

Plants in the genus *Tamarix*, know as tamarisk or saltcedar, have invaded sensitive riparian areas in the western US, causing substantial economic and ecological damage. A biocontrol program was developed by Jack DeLoach and his colleagues and was implemented beginning with open field releases of the northern tamarisk beetle, *Diorhabda carinulata*, in 2001. This presentation describes the history of the program as well as the current distribution of *D. carinulata* and three other *Diorhabda* species in North America. The presentation also summarizes information from several studies on the impact of *Diorhabda* on tamarisk across the west. Among the impacts are a 50-60% decline in tamarisk biomass, mortality averaging about 30% and a significant decrease in flowering which could diminish invasive potential of the shrubs. Ecosystem changes associated with tamarisk control include diminished evapotranspiration and diminished flammability of tamarisk. It also appears that biological control can decrease the competitive ability of tamarisk following disturbance events such as fire or flooding. A number of methods not commonly utilized in weed biocontrol have been employed in the tamarisk biocontrol program. These include remote sensing, population growth and phenology modelling, genomic sequencing and bioinformatics, semiochemical manipulation of weed biocontrol agents and plant ecophysiology methods to investigate biocontrol impacts. Incorporation of invasive plant biocontrol into riparian restoration strategies is discussed.

Managing Post-Fire Landscape Scale Toadflax Infestations Using Biocontrol and/or Herbicide. Sharlene Sing*; USFS Rocky Mountain Research Station, Bozeman, MT (139)

Integrated management of invasive toadflax in fire-affected areas is conventionally focused on either yellow toadflax (*Linaria vulgaris*) or Dalmatian toadflax (*L. dalmatica*). Confirmation of widespread naturally occurring hybridization of these two species has complicated the selection of management tools. Fire, already known to increase infestations of both parent toadflax species, may facilitate hybridization. Field evaluations and coupled genetic analyses have shown that the well-established *Mecinus* spp. toadflax stem mining weevils are closely associated with one primary host species and as such are unlikely to play a significant role in biocontrol of hybrid toadflax. Identifying effective herbicide treatments for hybrid toadflax is similarly challenging. A multi-year garden-based study indicated that field-collected hybrids may be more difficult to control with herbicide than either of the parental toadflax species. In areas affected primarily by Dalmatian toadflax, biocontrol with *M. janthiniformis* may provide gradual but effective stem density reductions.

Houndstongue Root Weevil: Montana's Science Advisory Panel and Efforts to Assess Non-target Impact in MT, WA, and ID. Melissa Maggio*[1], Bryce Christiaens[2]; [1]Montana Biocontrol Project, Missoula, MT, [2]Missoula County Weed District, Missoula, MT (140)

In 2019, the Montana Invasive Species Council (MISC) held a Science Advisory Panel (SAP) to scope the potential of approving the houndstongue root weevil (*Mogulones crucifer*) as a biocontrol agent in the U.S. The weevil is an approved and successful biocontrol agent in Canada and has naturally moved into parts of the U.S, where it is not an approved biocontrol agent and actually designated a plant pest. The panel consisted of researchers and regulators who addressed the concerns and produced a list of recommendations on how to move forward. One key recommendation was the development of a non-target impact assessment. The assessment project began in 2020 and is modeled after post-release research conducted in Canada. Currently, nine monitoring sites have been identified in Montana and surveys have been conducted in Washington and Idaho.

Inundative Biological Control Releases for Leafy Spurge Management: The Bureau of Land Management's Experience Using Biocontrol Along with Additional Options in an Integrated Weed Management Approach. Matthew J. Clarkson*; Bureau of Land Management, Idaho Falls, ID (141)

The BLM Upper Snake Field Office uses an Integrated Pest Management (IPM) program to control leafy spurge. This IPM program includes using chemical, manual, mechanical, and biological methods where appropriate. Leafy spurge is widespread throughout locations of the field office and each infestation comes with its own challenges and recommendations. Multiple factors are considered, including water, terrain, land uses, and public access before a treatment occurs. Once all factors have been evaluated, the USFO implements the most appropriate treatment for the area. Results have varying degrees of success but after years of treatments, certain situations can be expected to arise with each treatment method. While treating leafy spurge with any method is difficult to see progress, deciding on the goal for a site can make the difference in what is viewed as a successful treatment.

Canada Thistle Rust, a New Tool to Address a Persistent Foe. Dan Bean*, Karen Rosen; Colorado Department of Agriculture, Palisade, CO (142)

Canada thistle is a widespread problematic weed of agricultural lands, open spaces and riparian areas. No good biocontrol option was available until Dana Berner and his colleagues presented a method for establishing infections of thistle patches using the host specific rust fungus *Puccinia punctiformis*. Through a cooperative agreement between the USDA ARS and the Colorado Department of Agriculture we were able to implement Canada thistle biocontrol statewide. Results from a multi-year monitoring study conducted on private lands indicted a post-treatment stem density decline, after 4 years, averaging 60%. In the case of sites with existing infections the decline was well over 80%. These are promising results, but further work is needed to enhance infection rates, better understand the nature and movement of infections through the roots of Canada thistle and to characterize the impact of the rust fungus when used in conjunction with other control methods such as tillage, mowing and chemical treatments. In addition, we describe methods for identification and collection of the infective teliospores from the field and for processing teliospore rich plant material into usable material for inoculation of thistle patches. We also describe our implementation efforts within Colorado and within the western United States.

Russian Knapweed Biological Control Success with Host Specific Wasps and Midges. Sonya Daly*; Colorado Department of Agriculture, Palisade, CO (143)

Russian knapweed *(Rhaponticum repens*) is a perennial forb invading grazing land, rangeland, croplands, roadsides and riparian areas across Colorado. Colorado Department of Agriculture offers two biocontrol agents to help naturally control this invasive pest. The two biocontrol agents are *Jaapiella ivannikovi* (gall fly) and *Aulacidea acroptilonica* (gall wasp). Palisade Insectary established nursery or collection sites for both agents in Colorado. The CDA monitors the biocontrol agents' impact on this target pest species. The Palisade Insectary utilizes two monitoring protocols. Wasp stem galls were observed at high numbers at mentioned sites. The data collected resulted over 27,000 stem galls counted at a site near the Dolores River in Gateway, CO. The results indicated successful stem gall wasp establishment near river systems.

A Newly Approved Biological Control Agent for Yellow Starthistle: The Rosette Weevil, *Ceratapion basicorne*. Lincoln Smith*[1], Ikju Park[2]; [1]USDA-ARS, Albany, CA, [2]USDA Agricultural Research Service, Albany, CA (144)

Yellow starthistle is an invasive annual forb adapted to Mediterranean climate that has invaded over 19 million acres of rangeland in the Pacific West. It has been targeted for biological control since the 1960s. Seven species of insects that attack the flower heads and a rust pathogen have been intentionally introduced, plus another fly, *Chaetorellia succinea*, was accidentally introduced. A few of these species have become widespread, and may be affecting plant populations in some areas, but additional agents are needed. The rosette weevil is the first insect approved for introduction that attacks the immature, rosette, stage of this plant. The weevil's native region spans from Spain to Iran, and it has been reported to develop in the field only on yellow starthistle, cornflower and blessed thistle. In laboratory tests, 51 species of nontarget plants were tested for susceptibility to attack. Under no-choice conditions the weevil could complete development on Malta starthistle, bachelor's button, blessed thistle, safflower, and common crupina. Safflower, the most closely related crop species, was tested in seven field experiments in Turkey, one in France and one in Italy. Safflower was not attacked in any of these field experiments. The conclusions are that the weevil prefers yellow starthistle, but that it may also attack Malta starthistle, bachelor's button, and blessed thistle. USDA-APHIS issued a Finding of No Significant Impact (FONSI) in 2019, and a release permit has been issued for California. The first field release was made in Yolo County, CA in April 2020. The weevil has one generation per year. Adults emerge from hibernation in the early spring and feed on and lay eggs in rosette leaves. Larvae tunnel down the petioles and feed in the upper root area. Pupation occurs inside the plant, and adults emerge from plants at about the time that they are bolting (late spring). Adults feed and mate for a few weeks then disappear until the next spring. The weevil is expected to reduce the size and survivorship of plants, which should complement the existing agents, which attack flower head. Methods to artificially shorten the hibernation period have permitted producing two generations per year in the laboratory, which should increase production of adults for release.

Classical Biological Control of Invasive Annual Grasses in the Intermountain West. Brian Rector*[1], Massimo Cristofaro[2]; [1]USDA Agricultural Research Service, Reno, NV, [2]Biotechnology and Biological Control Agency, Rome, Italy (145)

This presentation provides a summary of research activities of the authors' laboratories to date on classical biological control of the annual invasive grass species cheatgrass (*Anisantha tectorum*), red brome (*A. rubens*), medusahead (*Taeniatherum caput-medusae*) and wiregrass (*Ventenata dubia*). Research has focused on searching for eriophyid mites on these grass species in their native Eurasian ranges, as well as other natural enemies. In addition, the target plants have been surveyed for the presence of natural enemies in their invaded ranges in the USA.

DISCUSSION SESSIONS

Project 1 Discussion Session: Pasture, Range, Forest, Rights of Ways, Wildland, and Aquatic Invasive Plants

Moderators: Shannon Clark, Bayer, Fort Collins, Colorado and Will Hatler, Corteva, Meridian, Idaho

Topic: *New Technologies for Combatting Invasive Weeds on Rangeland and Natural Areas.*

The Western Society for Weed Science held a discussion session on New Technologies for Combatting Invasive Weeds on Rangeland and Natural Areas.

Todd Neel: Drones are being used a lot in EDRR situations but how can we use drones beyond EDRR? Funding is an issue

Byron Sleugh: Banding funding together for drone research. The challenge is connecting neighboring states. We don’t have producer groups to fall back on like on the crop side.

Tim Prather: For universities resource allocation is the challenge. Partnering with someone is key i.e. drone spraying research.

Todd Neel: What progress has been made to use this technology?

Shannon Clark: What will the adoption rate be?

Byron Sleugh: Technologies are advancing fast. Laws and regulations are the issues.

John Coyle: Regulatory framework makes it hard for applicators to invest in the technology.

Bob Finley: In Wyoming two counties have spray drones. FAA is the impediment.

Byron Sleugh: The use of satellite imagery is increasing.

Todd Neel: Labelling issues around what constitutes an aerial application differs by stat, which makes using spray drones challenging. Drones present less impact on landscape compared to traditional aerial applications in terms of drift and off-target movement.

At the end of the discussion, the Western Society of Weed Science session chair solicited nominations for the next Weeds of Range, Forests, and Natural Areas chair-elect. Will Hatler nominated Lisa Jones from University of Idaho for incoming co-chair. Tim Prather seconded the motion. Lisa Jones was elected to serve as chair-elect in 2022 for Weeds of Range, Forests, and Natural Areas and agreed to accept the position.

Chair 2021:
Shannon Clark, Bayer, Fort Collins, CO 80525
shannon.clark.ext@bayer.com

Chair-Elect 2022:
Will Hatler, Corteva, Meridian, ID
william.l.hatler@corteva.com

Chair-Elect 2023:
Lisa Jones, University of Idaho, Moscow, ID
lisajones@uidaho.edu

Attendees:

Due to the virtual platform a list of attendees was not recorded.

Project 2 Discussion Session: Weeds of Horticultural Crops

Moderator: Harlene Hatterman-Valenti, North Dakota State University

Topic: *Weed Management Concerns for Specialty Crops.*

*Meeting minutes are not "verbatim" but serve as a general overview of the discussion.

The session began by discussing concerns with herbicide-resistant weeds in specialty crops and the lack of weed management tools in the toolbox. The discussion then moved to the use of technology for weed control in specialty crops. Concerns were mainly with the cost of the technology and how only high-value crops like lettuce where manual labor costs are already very high could be used. There was also discussion on the differences in weed management concerns for annual versus perennial specialty crops. Since Roger Batts was present, there was some discussion of the role of IR-4 and the need for more funds to this project. This led to discussion from a previous meeting and how some very old chemistry such as Kerb has been able to provide a niche service. The discussion ended on the topic of needing an integrated weed management approach, especially with all the multiple-herbicide-resistant weeds.

A business meeting was conducted at the end of the discussion session with Elizabeth Mosqueda elected as chair-elect for 2022. During this time there was discussion of a possible tour during the 2022 meeting, since the meeting location is ideal for horticultural crop production. Members from California attending the meeting were asked to look into the tour possibility. Discussion on a topic for the 2022 meeting also occurred with the decision to have the 2022 chair and 2023 chair-elect decide the topic.

Chair 2021:
Harlene Hatterman-Valenti, North Dakota State University.
h.hatterman.valenti@ndsu.edu

Chair-Elect 2022:
Marcelo Moretti, Oregon State University
marcelo.moretti@oregonstate.edu

Chair-Elect 2023:
Elizabeth Mosqueda, California State University
elmosqueda@csumb.edu

Attendees:

Name	
Harlene Hatterman-Valenti	Pamela Hutchinson
Brad Hanson	Elizabeth Mosqueda
Marcelo Moretti	Jesse Richardson
Joel Felix	Ed Peachey
Roger Batts	Kai Umeda

Project 3 Discussion Session: Weeds of Agronomic Crops

Moderators: Joseph Ikley, North Dakota State University

Topic: *Herbicide-Resistance Management in Minor and Specialty Crops.*

*Meeting minutes are not "verbatim" but serve as a general overview of the discussion.

The session began by discussing a presentation given previously by Joseph Ikley on herbicide-resistant Palmer amaranth discovered in sunflower screenings used as a cattle feed. The discussion of sunflower screening introduced the larger issue of herbicide-resistant seed movement in livestock feed throughout the country. The regulation of seed movement in various states throughout the country soon became the major focus point. In particular, the contaminated sunflower screenings in North Dakota are not regulated despite Palmer amaranth being a noxious weed within the state. Attendees reported that a similar lack of regulation and enforcement exists in many other states. Limiting weed seed spread in animal feed and manure was agreed to be a critical need for preventing the spread of future resistant populations. Continuing older research conducted on seed longevity in manure was brought up as potential future avenue for research. Current work at the University of Minnesota is ongoing to identify Palmer amaranth seed in manure. Certified manure already exists in some parts of the country, particularly Washington State to prevent herbicide-contaminated manure from being used in sensitive crops. That certification framework, along with certified grass seed regulations, could serve as a framework for a future certification process. Given the interest in seed movement a proposed topic for the 2022 discussion session is *Weed seed movement in animal feed and manure*.

Side discussions included:

- Millet seed and CRP seed are additional sources of movement of herbicide-resistant weed seeds.
- The use of alternative control methods for control of herbicide-resistant weeds in specialty and minor crops due to lack of alternative herbicide options was discussed. Specifically electrical currents, the "Organic Weed Puller", and the wick wiping.
- Regardless of the region, there is a lack of herbicide option in specialty crops and also a lack of herbicide option in rotational crops due to carry over concerns.
- Several older, high use rate, herbicides were brought up including metamitron in sugarbeet and chloramben in dry bean as potential herbicides that can be used for new resistance cases, however there would be difficulty in bringing older products to the market.
- A lack of survey data makes tracking novel herbicide-resistance weeds challenging across regions. Many commodity groups and funding sources are unwilling to fund survey work each year.

Business Meeting

Steve Valenti was elected as Agronomy Section Chair-elect in 2023.

Chair 2021:
Joseph Ikley, North Dakota State University, PO BOX 6050, Fargo, ND 58108-6050
joseph.ikley@ndsu.edu

Chair-elect 2022:
Nevin Lawrence, University of Nebraska, Scottsbluff, NE 69361
nlawrence2@unl.edu

Chair-elect 2023:
Steve Valenti, Bayer Crop Science
stephen.valenti@bayer.com

Name	
Joseph Ikley	Pamela Hutchison
Nevin Lawrence	Ian Burke
Jody Gale	Steve Valenti
Scott Cook	Greg Dahl
Jill Schroeder	Alan Haack
Roger Batts	Breanne Tidemnn
Harlene Hatterman-Valenti	

Project 4 Discussion Session: Teaching and Technology Transfer

Moderator: Breanne Tidemann

Topic: *Tips and tricks to Make Your Virtual Presentation Zooooooom*

Techniques and Ideas suggested:

- Arrive early to prepare
- Play music before the presentations starts (attendees know everything is working)
- Engage your audience early
- Make sure you sound level is adequate and your headset is working and charged
- Make sure the lighting is good
- Check what is in your background
- Chat with attendees before the presentation, be uplifting
- Show enthusiasm and be energetic
- Show your personality and sense of humour
- Let the audience see you smile or at least hear your smile if you aren't on camera.
- Have a positive attitude
- Try and infuse fun
- Try and keep the presentation captivating
- Be creative
- Use upbeat colours – note, upbeat, not obnoxious
- Bring humour (think comic or funny video clip, but keep it appropriate!)
- Be approachable
- Keep things interactive and participatory (polling is a great and quick option)
- Get some dialogue going – use the chat, the Q&A, or breakout rooms
- Know when to stop
- Be prepared for issues. Stay calm, don't apologize
- Restart your computer prior to your presentation
- Turn your cell phone off and ask attendees to do the same
- Set up breaks if the presentation is over an hour
- Thank those who helped you.

We had on ongoing discussion around polling, which can be done in zoom webinars but not in zoom meetings. Attendees had used polling to identify who was there in order for them to get credits. One attendee mentioned PollAnywhere as an option that could be used across multiple formats (including youtube, facebook, etc.). This led to another discussion on the fact that meetings can be streamed on multiple formants. Another option that was mentioned for attendees to get credits was to include a key word at some point during your talk. At the end of the talk attendees are given a link where they need to go and input the keyword that was given during your talk to get their credits.

We discussed how important it is to have an army of people working on virtual webinars, with each on having their own duty (main presenter, chair, someone watching chat, someone helping with technical difficulties, etc.). It can also be helpful to have a second chair or an assistant to the chair that clears off Q&As as they are answered so the chair can see the next upcoming question. The goal is to be like a duck on water – look very calm on the surface that the audience sees, even if it's a bit chaotic in the background.

We discussed breakout rooms. Identified that it's important that they are easily set-up/entered and that it's well communicated otherwise it can cause frustration. If you are assigning rooms make sure the group cohort makes sense otherwise you may not get as much interaction/dialogue as you are looking for, or room members may feel frustrated.

There was a question on whether or not you can tune in to two Microsoft Teams meetings at the same time but the group wasn't sure on if that feature is available.

There were some questions around how to use music at the start. The experience of one attendee was that they built a video advertising upcoming meetings and they put the music behind using video editing software. She also had to hit play every 3 minutes or so as that was the total length of the video. It's important to check copyright and royalties on the music you choose, especially if you are recording and posting the webinar.

Overall we agree that you can't base success on attendance at a presentation or webinar but on the impact of that webinar.

Chair-elect:
Moving to the business portion of the discussion section, Breanne Tidemann will be chair of the Project in 2022 but we needed a new moderator/vice-chair. Chris Mayo nominated Jeanne Falk-Jones, the nomination was seconded by Drew Lyon. Jeanne accepted the nomination and with no other volunteers or nominations she was acclaimed into the position.

<u>Chair 2021:</u>
Chris Mayo, Bayer CropScience
christopher.mayo@bayer.

<u>Chair-elect 2022:</u>
Brianne Tidemann, Agriculture and Agri-Food Canada
breanne.tidemann@canada.ca

<u>Chair-elect 2023:</u>
Jeanne Falk-Jones, Kansas State University
jfalkjones@ksu.edu

Name	
Drew Lyon	Greg Dahl
Janne Falk-Jones	Scott Cook
Pam Hutchinson	Joan Campbell
Chris Mayo	Breanne Tidemann
Roger Batts	

Project 5 Discussion Session: Basic Biology and Ecology

Moderators: O. Adewale Osipitan, University of California, Davis, CA

Topic: *What High Throughput Data Can Teach Us About Weed Biology and Control?*

High throughput data has the potential to bring innovation and ground-breaking discoveries to weed science. High throughput is a robotic or computer system for rapid collection and/or processing of data or biological materials from a very large samples, that would ordinarily require a great amount of time and labor if done manually. With high throughput, large datasets can easily be generated and utilized to address very complex questions. Some relevant examples include robotic extraction of DNA, sequencing multiple DNA molecule in a parallel manner, at a time (high throughput sequencing), rapid nondestructive imaging technology for phenotyping very large biological samples (high throughput phenotyping), rapid test of millions of chemical and genetic materials in drug/herbicide discovery (high throughput screening) and use of drones for collection of large amount of images and the analysis, which is useful in developing technology for biological identification and for building a robotic weed control device.

Participants during the discussion believe that high throughput devices and data are important resources for weed biology and control as highlighted above. However, a key question was about the possible limitations to the use of high throughput devices/methods for research in weed biology and control. Some of those identified limitations were cost of acquiring a high throughput device; and limited knowledge and skill set required to utilize high throughput devices, collect data and analyze data. It was specifically mentioned that most often, specialized data science skills are needed to properly analyze complex meta-data associated with the use of high throughput, and very few students and even weed science faculty have this data science skills. However, it was suggested that this lack of data analysis skill can be overcome if students are encouraged to take data science classes as part of their university program of study. In respect to cost of high throughput device, it was also opined that weed research grants can be secured if the benefits of utilizing a high through device/data, such as the ability to answer very complex research questions, are well articulated in a grant proposal. Examples of institutions in the United States where high throughput related devices are being acquired and utilized for weed science research were provided. These include the use of robotic devices for physical weed control with components like abrasives, lasers, cultivators, propane flaming and high-pressure water in vegetable crops at the University of California-Davis; robotic device for selective herbicide weed control in vegetable crop at the University of Florida; development of hyperspectral imaging technology through collection and analysis of thousands of tomato plant images for identification of parasite infested tomatoes at the University of California-Davis; weed identification and discrimination studies using large scale image collection with drones at Texas A&M, Montana State University, among others. Some weed research groups also have collaborations that allow the use of high throughput systems for DNA extraction and sequencing for their research. In this regard, an example of small grain USDA lab at Kansas State University was mentioned.

It was also mentioned that efforts are being made to develop a system using drone for large scale and precision herbicide spraying, and assessing herbicide injury on the field. An unpublished data showed that weed science accounted for about 26% of artificial intelligence (which is a bedrock for developing high throughput systems) studies in agricultural science. These are pointers to how importance the understanding and utilizing high through systems are to weed science.

Chair 2021:
Neeta Soni, Corteva AgriScience
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Chair-elect 2022:
O. Adewale Osipitan, University of California, Davis, CA
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Chair-elect 2023:
Rui Liu, Kansas State University Hays, KS
tabitha723@ksu.edu

Attendees:

Name:	**Affiliation:**	**Email Address:**
Sandra McDonald	Mountain West Pesticide Education and Safety Training	sandra@mountainwestpest.com
Jill Schroeder	New Mexico State University	jischroe@nmsu.edu
Rui Liu	Kansas State University	Tabitha723@ksu.edu
Adewale Osipitan	University of California, Davis	oosipitan@ucdavis.edu

WESTERN SOCIETY OF WEED SCIENCE NET WORTH REPORT

April 1, 2020 through March 31, 2021

ASSETS	
Cash and Bank Accounts	
American Heritage Checking	$35,259.98
American Heritage Money Market	$58,207.40
CD#3	$25,463.95
CD#4	$25,351.23
CD#5	$25,000.00
CD#6	$25,603.60
CD#7	$25,730.26
TOTAL Cash and Bank Accounts	$220,616.42
Investments	
RBC Dain Rauscher Account	$210,346.05
TOTAL Investments	$210,346.05
TOTAL ASSETS	$430,962.47

WESTERN SOCIETY OF WEED SCIENCE CASH FLOW REPORT

April 1, 2020 through March 31, 2021

INFLOWS ($)	
Annual Meeting Income	89,848.43
Interest Income	410.31
Dividend Income	3,618.90
Membership Dues	8,200.74
Rita Beard Endowment	75.00
Royalty for Proceedings - RPR	1,051.99
Security Value Change	31,971.77
Student Travel Account	1,100.00
Sustaining Member Dues	11,800.00
TOTAL INFLOWS	**148,077.14**
OUTFLOWS ($)	
Annual Meeting Filing Fee	20.00
Annual Meeting Expense	5,334.39
Mobile Meeting App	29,223.00
Total Annual Meeting Expense	**34,557.39**
Bank Charge	1,826.03
CAST Annual Dues	1,500.00
Copies	150.00
Director of Science Policy	12,423.00
Fee Charged	2,083.67
Insurance	525.00
Management Fees	23,058.40
Miscellaneous	821.60
Mobile Deposit Fee	72.50
Proceedings/Publications	750.00
Postage	11.90
Summer Meeting	1,358.93
Student Awards	3,818.03
Taxes	365.00
Travel to Summer Meeting	419.10
Travel to WSWS Meeting	1,500.00
Virtual Terminal Fee	812.55
Social Media	1,000.00
Web Site Hosting	4,000.00
TOTAL OUTFLOWS	91,073.10
OVERALL TOTAL	$57,004.04

WSWS 2021 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.

Carl Libbey - Fellow Public Sector, Washington State University

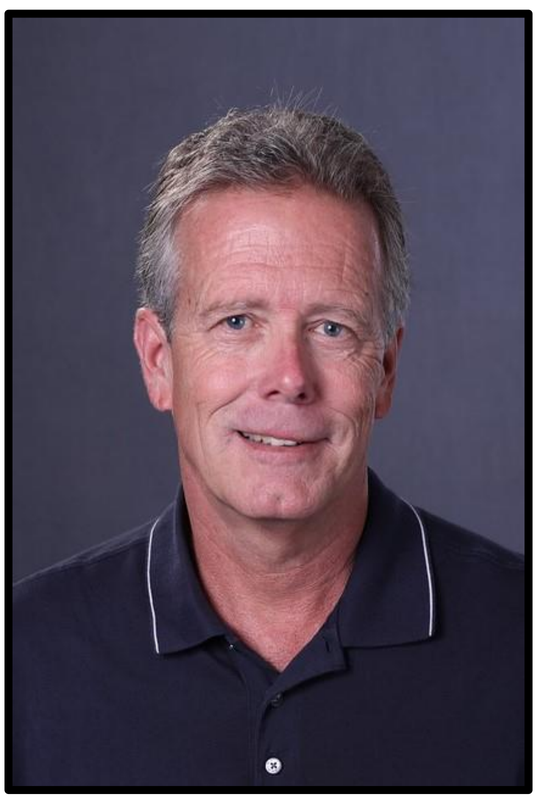
Carl Libbey, a native of Whidbey Island in the Pacific Northwest, completed his bachelor's degree in Horticulture at Washington State University in 1983. In the summer of 1980, while attending WSU, he began his official Weed Science career when he was hired as a summer research assistant for the Weed Science program at the Northwestern Washington Research and Extension Unit in Mount Vernon. After graduating he was employed in the ornamental nursery industry in Oregon until relocating back to the Skagit Valley when he became an Agricultural Research Technologist at the "experiment station". He was employed in Mount Vernon for the next 35 years working under the direction of Dwight Peabody, Stott Howard, Kassim Al-Khatib, and Tim Miller. There he oversaw day to day operations that included conducting field and greenhouse experiments. In 1990 he attended his first WSWS meeting in Reno and has been participating in almost all of them ever since with over 15 poster presentations. He has been active in the WSWS by being a member of the Poster Committee. Carl has been the newsletter editor or coeditor since 2011 and in 2018 he was asked to take on the role of the proceedings editor. He received the Professional Staff Award in 2007 and in 2014 was given the Presidential Award of Merit by then President Roger Gast.

Charlie Hicks - Fellow Private Sector, Bayer Crop Science

Charlie Hicks has a BS degree in Agronomy from the Ohio State University and an MS degree in Weed Science from Purdue University. Charlie began his career in Weed Science in Southern Indiana with a summer internship at Mobil Chemical. Since then, through mergers and acquisitions, he has worked with some 7 different companies over the years, often not by his own doing! Could be an industry record?

Charlie is a Field Agronomist with Bayer CropScience based in Fort Collins, Colorado covering CO, WY, MT and Western NE. Over the past 30 years, he has screened and help bring to market several important active ingredients and herbicide safeners across a wide range of cropping systems. More importantly, Charlie has established a high level of trust and an excellent working relationship with many university cooperators, crop consultants and growers.

Charlie has been a member of the WSWS since 1987 and has enjoyed serving the society in many roles. His activities include: Chair of the Education and Regulatory Session and board member 2005, Member at Large 2018, Sustaining Members Committee, Poster Committee and Site Selection Committee, Graduate Student Poster and Paper Contest Judge. He has been the host of the Graduate Student Luncheon since 2001, the Moderator of the What's New in Industry session since 2010 and was named the WSWS Outstanding Weed Scientist in 2014. In addition, he presented 14 oral papers at WSWS meetings over the years and co-authored many more.



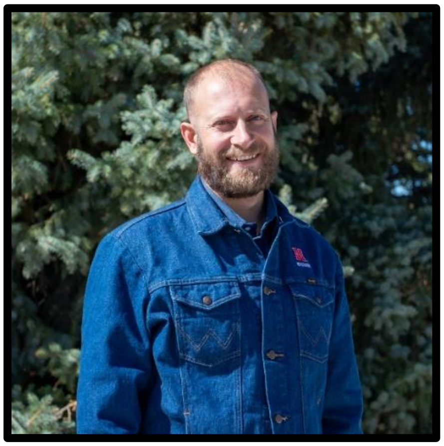
WSWS 2021 HONORARY MEMBER

Michael Walsh, University of Sydney, Australia

Michael Walsh is an Associate Professor and Director Weed Research at the University of Sydney. Michael completed his B.Sc. at the University of Western Australia, M.Sc. from La Trobe University, Melbourne, and PhD from the University of Wyoming. He joined the Australian Herbicide Resistance Initiative, at the University of Western Australia in 1999 where he focussed on the development and introduction of harvest weed seed control systems. Michael has spent 20 years working on the development of alternative weed control techniques and believes that recent technological advances are creating exciting opportunities for the future use of new weed control techniques.

WSWS 2021 OUTSTANDING WEED SCIENTIST AWARDS

Nevin Lawrence



The Outstanding Weed Scientist, Early Career was awarded to Nevin Lawrence. Dr. Lawrence is an assistant professor and Integrated Weed Management Specialist with the University of Nebraska-Lincoln located at the Panhandle Research and Extension Center near Scottsbluff, Nebraska. He completed his B.S. degree in agroecology at the University of Wyoming, his M.S. in agronomy also at the University of Wyoming, and his Ph.D. in crop science at Washington State University. Dr. Lawrence's research and extension focus is the development of weed management programs that leverage crop rotations and other cultural practices to supplement the sometimes-limited weed control options available in Western Nebraska. Specific projects include measuring the impact of narrow-row and direct-harvest dry bean production on weed communities, controlling herbicide-resistant kochia and pigweed species using multi-year integrated management plans, and determining the influence of climate on weed abundance and management. Non-crop projects include the evaluation of novel weed control products for control of downy brome in rangeland. He is the lead Nebraska researcher on a multi-state project focused on developing rubber dandelion (*Taraxacum kok-saghyz*) into a domestic form of natural rubber. Dr. Lawrence has been awarded more than $500,000 of external funding and published 19 peer-reviewed publications. He has also coauthored 11 peer-reviewed extension publications and written 24 popular press articles for a variety of outlets.

Prashant Jha

The Outstanding Weed Scientist, Public Sector was awarded to Prashant Jha. Dr. Jha is an Associate Professor and Extension Weed Specialist at Iowa State University since May 2019. He completed his B.S. in Agriculture and M.S. in Agronomy at CCS Haryana Agricultural University, Hisar, India and his Ph.D. in Plant and Environmental Science at Clemson University, Clemson, South Carolina. Prior to Iowa, he was an Associate Professor of Weed Science with Montana State University located at the Southern Agricultural Research Center, Huntley, Montana (2010-2019). His research program is focused on improved understanding of weed biology and ecology to develop effective, integrated weed management (IWM) strategies in agronomic crops, optimization and stewardship of herbicide use, and developing sustainable IWM solutions to manage herbicide resistance and other factors influencing weed population dynamics in agroecosystems. He has led the statewide weed control programs at Montana State University for 9 years and now at Iowa State University, with the ultimate aim to develop cost-effective and sustainable weed control recommendations for wheat, barley, pulse crops, sugar beet, alfalfa, corn, and soybean producers. His extension programming supports agribusiness governmental agency programs, and other educational needs throughout the state. He has secured a total of $9.2 million in competitive grants and contracts since 2010. He has published over 80 refereed journal articles and book chapters, 60 extension articles, and 183 conference proceedings and delivered more than 75 extension or invited presentations in various grower, commodity and industry meetings. Dr. Jha has mentored 6 MS level, 3 PhD level and 10 undergraduate students, and 3 postdoctoral researchers. He is the recipient of Early Career Weed Scientist awards from the Weed Science Society of America and the Western Society of Weed Science. He serves as an Associate Editor for Weed Science and Weed Technology journals. Dr. Jha has served on the WSWS Board of Directors and has been a member and chair of several committees in the WSWS, the WSSA, and other international weed science societies.

WSWS 2021 WEED MANAGER AWARD

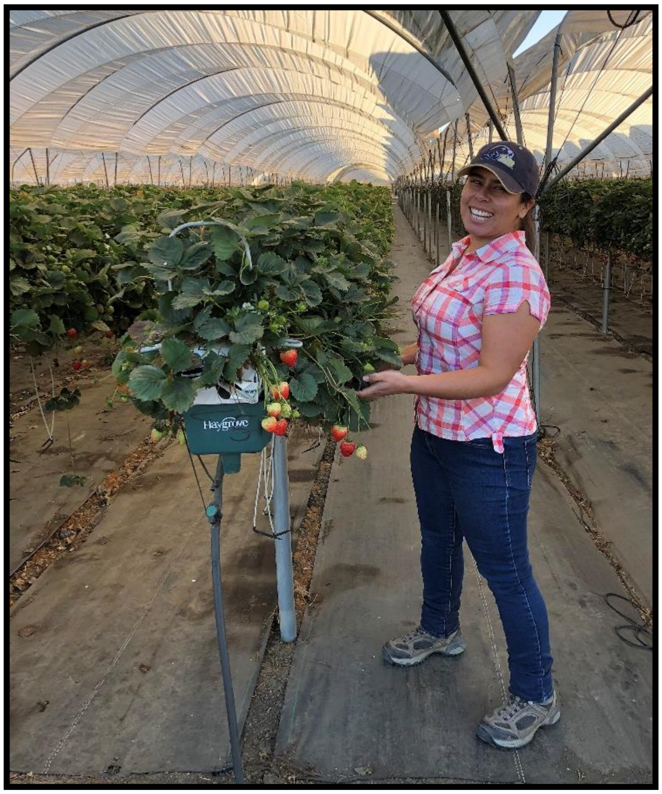
This award was not conferred in 2021

WSWS 2021 PROFESSIONAL STAFF AWARD

This award was not conferred in 2021

WSWS 2021 PRESIDENTIAL AWARD OF MERIT

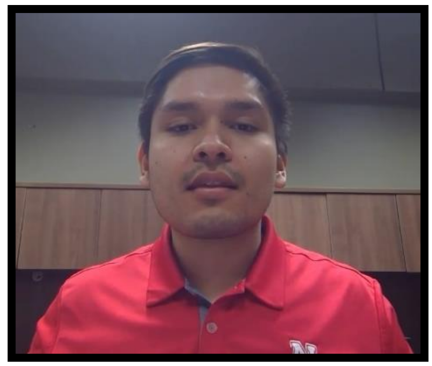
Elizabeth Mosqueda



Elizabeth Mosqueda received the WSWS Presidential Award of Merit from Corey Ransom for her leadership of the Diversity and Inclusion Committee.

WSWS 2021 ELENA SANCHEZ MEMORIAL STUDENT SCHOLARSHIP RECIPIENTS

Craig Alford, Awards Committee Chair announced the recipients of the "WSWS Elena Sanchez Outstanding Student Scholarship Program" were Mirella Ortiz (Colorado State University) – Ph.D. graduate student and Joshua Miranda (University of Nebraska) – M.S. graduate student. A big thanks to their advisors for bringing along such great promising talent for the future of weed science.



WSWS 2021 RITA BEARD ENDOWMENT STUDENT SCHOLARSHIP

The Rita Beard Endowment Foundation Board of Trustees did not award scholarships in 2021 due to COVID travel restrictions in place. The Rita Beard Endowment Foundation is a 501 (c) (3) non-profit that was created from a generous donation from Rita Beard's family and friends to support students and early career invasive species managers with educational opportunities by providing registration and travel to professional meetings including: Society for Range Management, Western Society of Weed Science, Western Aquatic Plant Management Society and the North American Invasive Species Management Association. To read more about the Foundation, learn how to apply for the 2022 scholarships, or make a donation go to: **http://www.wsweedscience.org/rita-beard-endowment-foundation/**.

WSWS 2021 STUDENT PAPER AND POSTER AWARDS

The 2021 virtual WSWS Student Contest had 20 participants in the oral presentations, divided into 3 judging sections and 16 students prepared posters broken out into 3 judging sections, including 2 individuals in the undergraduate poster section. The Student Paper Judging Committee for 2021 consisted of Dennis Scott as chair with Josh Adkins and Carl Coburn as members. We express appreciation to the additional 12 professionals that served as judges this year. Thank you, Clarke Alder, Ryan Rapp, Joel Felix, Albert Adjesiwor, Clint Beiermann, Jacob Fischer, Shannon Clark, Stacey Swanson, Andrew Kniss, Richard Zollinger, Brad Hanson and Terry Mize.

On behalf of the WSWS we thank all the students that put themselves out there and did the work to participate in this year's Student Contests. Here are the results as announced at the Business meeting Thursday morning.

Oral – Section 1-Weeds of Range, Forestry, and Natural Areas, 6 eligible participants

1st prize- Mirella Ortiz- Colorado State University
Understanding Auxin Herbicides for Aquatic Plant Management

2nd prize- Natalie Fronk- Utah State University
Considerations of Life Cycle in Invasive Mustard Management

Oral – Section 2- Weeds of Agronomic Crops, 7 participants

1st prize- Ednaldo Borgato- Kansas State University
Metabolic resistance to PPO-inhibitors in a six-way-resistant Palmer amaranth population from Kansas

2nd prize- Hannah Lindell- Oklahoma State University
Effect of Planting Date Window and Herbicide Selection on Rescuegrass (Bromus catharticus) Management in Winter Wheat

Oral – Section 3 Weeds of Horticultural Crops, Basic Biology and Ecology, Teaching and Technology, 6 participants

1st prize- Chandrima Shyam- Kansas State University
Enhanced metabolism of 2,4-D in 2,4-D resistant Palmer amaranth population from Kansas

2nd prize- Lydia Fields- Washington State University
Assessment of Light Activated Sensor Controlled Spray Technology in Eastern Washington Fallow Systems

Poster – Section 4 Weeds of Horticultural Crops, Basic Biology and Ecology, Weeds of Range, Forestry and Natural Areas, 5 participants

1st prize- Jacob Courkamp- Colorado State University
Effects of Indaziflam Treatment on Seed Bank Density and Richness in a Sagebrush-grassland Plant Community in Sublette County, WY.

2nd prize- Natalie Fronk- Utah State University
African Mustard Response to Treatment Over Time

Poster – Section 5 Weeds of Agronomic Crops, 9 participants

1st prize- Joshua Wa Miranda Teo- University of Nebraska
Palmer Amaranth Interference and Seed Production in Dry Edible Bean.

2nd prize- Prashasti Agarwal- New Mexico State University
Weed Suppression versus Water Use: Can Cover Crops be Sustainable in Water Limited Agroecosystems?

3rd prize- Samuel Revolinski- Washington State University
Genetic Architecture of Flowering Time Traits in Bromus tectorum of the Pacific Northwest

Poster – Section 6 Undergraduate Competition, 2 participants

1st prize- Liliana Fendler- Colorado State University
Constructing a Synthetic EPSPS Copy Number Variation System to Assess Fitness and Glyphosate Resistance

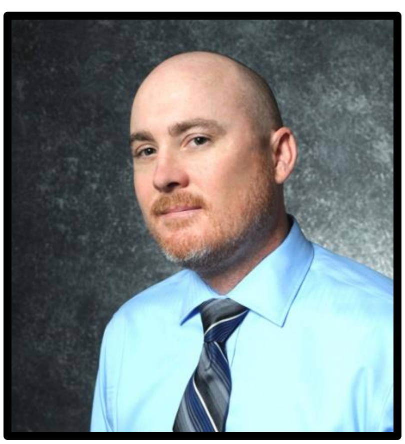
Submitted by Dennis Scott – Chair
Student Paper Judging Committee

WSWS 2021 ANNUAL MEETING NECROLOGY REPORT

At the Thursday business meeting, the WSWS members who passed away this year were honored with a moment of silence. Those members were:

James (Jim) Gray (1959–2019)

Jim passed away on Saturday, November 23, 2019 at St. Luke's Hospice House in Kansas City, Missouri. He was born in Durango, Colorado on March 11, 1959. After graduating from high school in Durango, Jim attended Colorado State University, where he studied soil science and agronomy, receiving his bachelor's degree in 1981. In 2016, Jim was named an Honored Alumni of the Colorado State University Soil and Crop Science Department. After graduation, Jim launched into a decades-long career in the agricultural industry, specializing in regulatory and environmental affairs. Over the years, he served as the Director of Regulatory and Environmental Affairs at the Western Crop Protection Association and in similar positions with top-tier agricultural corporations such as Rhone-Poulenc Ag, Aventis CropScience and Bayer CropScience. At the time of his passing, Jim was the President of Gray Executive Direction, LLC and Executive Director of the Industry Task Force II on 2, 4-D Research Data, a position he had held since 2007. Jim was an extremely well-respected member of the agribusiness community in Kansas City and across the United States and received many accolades. Jim also went out of his way to support aspiring professionals in the agricultural industry, often acting as a mentor and sounding board both personally and professionally. He could always be counted on for a smile, a positive word and promised action.



Travis Bean (1977-2020)

Travis passed away on May 27, 2020 at the age of 43. Travis was born in Lincoln, NE on February 11, 1977 and moved with his family to Yuma, AZ in 1981 where he lived until high school graduation. Travis then attended the University of Arizona in Tucson, AZ, where he earned his bachelor's degree in Plant Science in 2000, master's degree in Range Management in 2002, and Ph.D. in Ecology and Management of Rangelands in 2014. His dissertation research addressed management of the invasive weed buffelgrass, and was recognized by a Public Service Award from the University of Arizona School of Natural Resources and Environment and a United States Department of Interior Partners in Conservation Award. Travis joined the UC Riverside Department of Botany and Plant Sciences in 2014 as a weed scientist with expertise in weed management in wildland, rangeland, and agricultural settings. There he developed a research and Extension program focused on managing weedy and invasive plants in agriculture and wildland settings. Travis was a great contributor to weed research and Extension in California and the western United States and his loss will be felt greatly by his friends and colleagues throughout the weed science community.

E. Stanley Heathman (1927-2020)

Stanley was born May 9, 1927 and passed away in November 2020 in Tucson, AZ. He attended Kansas State University and enlisted in the army from 1945-1947. He married Katherine D. Edwards. Stanley was the Extension Weed Specialist in the Plant Sciences Department at the University of Arizona up until the early 1990's. He worked on weed management issues in crops such as cotton, small grains, and forages. He was the president of WSWS in 1985 and named a fellow of the society in 1988.

1988 WSWS fellows: Harvey Tripple (Left) and Stanley Heathman (Right)

WSWS 2021 ANNUAL MEETING RETIREES REPORT

Since the last meeting, a total of one member of the society was brought forward as new or soon to be retired from the Western Society of Weed Science. The lone member was formally recognized at the Business Meeting. His attendance, years of service, and professional leadership will be greatly missed.

Tim Harrington, Research Forester, USDA Forest Service PNW

Submitted by Pat Clay, Immediate Past President

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