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2017

PROCEEDINGS

OF

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PREFACE

The Proceedings contain the written abstracts of the papers and posters presented at the 2017 Western Society of Weed Science Annual Meeting plus summaries of the research discussion sections for each Project. The number located in parenthesis at the end of each abstract title corresponds to the paper/poster number in the WSWS Meeting Program. Authors and keywords are indexed separately. Index entries are published as received from the authors with minor format editing.

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Proceedings Editor: Bill McCloskey, University of Arizona

2017

PROCEEDINGS

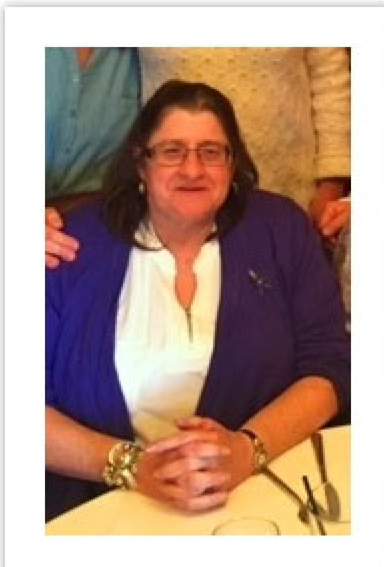
OF

THE WESTERN SOCIETY OF WEED SCIENCE

ARE DEDICATED

TO

RITA BEARD



Rita Beard, a luminary in the federal and private sector of the invasive species world, passed away in October 2016 at her home in Fort Collins, CO. Throughout her career, Rita advanced her vision of coordinating invasive species management on a national scope. By encouraging collaboration from the field to congressional levels, she effectively changed the way invasive species are managed in this country. In addition, she worked to make sure that all invasive species management decisions were based on the latest and best available research and technology, thus ensuring that management decisions were supported by science. Towards that end, Rita spearheaded the development of the original mapping standards for the North American Invasive Species Management Association (NAISMA), which unified management practices to help ensure consistent data collection.

To learn more about Rita: http://www.wsweedscience.org/rita-beard-endowment-foundation/

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POSTER SESSION

Undergraduate Posters

Understanding the Effects of Herbicide Application on Hoary Alyssum (*Berteroa incana* L.) Seed Biology. Uriel D. Menalled*, Stacy Davis, Jane Mangold; Montana State University, Bozeman, MT (001)

Hoary alyssum (*Berteroa incana*), a non-native, invasive mustard species, can be difficult to manage because of its long flowering period, during which plants simultaneously flower and produce seeds. Consequently, improper herbicide application may kill hoary alyssum flowers but not seeds. Since hoary alyssum reproduces exclusively by seed, we examined how different herbicides affect hoary alyssum seed production and viability. Invasive plant managers treated hoary alyssum plants with various herbicides on six rangeland sites across southwestern Montana in summer 2016. Managers recorded flower and seed pod development of the hoary alyssum at their sites. We randomly selected 20 to 30 hoary alyssum plants from treated and non-treated areas at each site about four weeks post-treatment. From these plants, we determined seed production and analyzed seed viability using tetrazolium tests. At four of six sites, herbicide treatments reduced hoary alyssum seed production by 49 to 98% compared to non-treated areas. Notably, herbicide treatments significantly reduced seed production at all sites that were sprayed at early developmental stages, or before 50% of hoary alyssum flowering stems had seed pods. All herbicide treatments, except for chlorsulfuron + 2,4-D, significantly decreased hoary alyssum seed viability. Seed viability in non-treated areas ranged from 36 to 73%. Seeds from treated areas, except those treated with chlorsulfuron + 2,4-D, exhibited 0 to 21% viability. Our research suggests that the application of some herbicides early during hoary alyssum flower and seed pod development can effectively reduce seed production and viability, controlling this invasive plant's sole method of propagation.

Exploring Novel Ways to Manage Downy Brome (Bromus tectorum L.) in Agronomic Systems in the Inland Pacific Northwest (PNW). Hannah C. Lindell*, Amber L. Hauvermale, Ian C. Burke; Washington State University, Pullman, WA (002)

Downy brome is an invasive weed species prevalent in small grain production regions of the Pacific North West (PNW). Brome is difficult to manage due to variation in seed dormancy and there are limited herbicide control options. Estimates of mature seed set were combined with seed dormancy screens to parameterize four seed dormancy scenarios across the PNW. In addition to dormancy scenarios, our objective was to create a detailed developmental scale to predict seed maturity. The Feekes scale was used as a model to measure developmental stages through mature seed set. Developmental ratings were measured in a large field study consisting of 250 biotypes collected from across the PNW. The field study, located in Central Ferry, WA, was arranged in a randomized block design with six biological replicates for each biotype. Interestingly, while preparing downy brome seed for the Central Ferry study, the fungal seed treatment mix containing thiamethoxam, mefenoxam, and fludioxonil (Cruiser Maxx) inhibited germination. Germination dose response curves evaluating five seed treatment concentrations were used to inhibit seed germination in downy brome, wild oat, and Italian ryegrass. At the highest seed treatment concentration (30 mL/220 kg), percent germination for downy brome, wild oat, and Italian ryegrass were 37.6%, 55%, and 32.5%. Italian ryegrass germination was also inhibited at lower seed treatment concentrations at 15 mL/220 kg, 7.5 mL/ 220 kg, or 3 mL/ 220 kg fungicide. Future research will look at the effect of individual seed treatment active ingredients on inhibiting seed germination in grass weeds.

Characterizing Herbicide Resistant Kochia in Utah. Megan Nielsen*, Corey V. Ransom, Heather E. Olsen; Utah State University, Logan, UT (003)

Kochia scoparia is known to be resistant to ALS herbicides including chlorsulfuron. Currently, only one case of resistance is documented in Utah. This work was undertaken to document the occurrence of chlorsulfuron-resistant kochia populations within Utah and to characterize the level and basis of that resistance. Seed samples were collected in 2014 from 85 locations throughout Utah. Initial screening identified 52 populations as moderately to highly resistant. From the initial screening, 10 populations were selected for further characterization. These included populations that were believed to be susceptible (4), have low resistance (2), moderate resistance (2) and high resistance (2). A single plant was selected from each population and clonally propagated by cuttings to generate enough plants to conduct dose response trials. Plants varied in size between the four runs and rates were adjusted within runs to better capture response of different populations. Dose response trials included nine rates of chlorsulfuron and an untreated control. Treatments were applied with a CO_2-pressurized enclosed track sprayer and replicated four times. Visual evaluations, plant height and dry weight were taken 21 to 28 days after treatment.

Based on plant biomass, GR_{50} values for the susceptible populations ranged from 1.52 to 42.4 g ai ha^{-1}, while GR_{50} values for resistant populations ranged from 20 to greater than 2,000 g ai ha^{-1}. Vegetatively propagated kochia growth is highly variable and is a challenging model for conducting dose response experiments. Genetic analysis will confirm the basis for the resistance in these kochia populations.

Pyroxasulfone Weed Management Systems in Oklahoma Winter Wheat. Grace K. Ogden*[1], Misha R. Manuchehri[1], Adam C. Hixson[2]; [1]Oklahoma State University, Stillwater, OK, [2]BASF, Lubbock, TX (004)

The use of preemergence (PRE) herbicides in Oklahoma winter wheat may improve the control of acetolactate synthase resistant Italian ryegrass [*Lolium perenne* L. spp. *Multiflorum* (Lam.) Husnot]. Two studies were conducted at the Cimarron Valley Research Station near Perkins, OK in 2016 to evaluate weed management systems that included pyroxasulfone and pyroxasulfone +

carfentrazone applied PRE or very early post (VEPOST). Visual weed control and crop response were evaluated 4, 6, 9, and 13 weeks after planting (WAP). Six WAP, the highest levels of wheat injury (7 to 14%) occurred following VEPOST applications of metribuzin or flufenacet + metribuzin. Italian ryegrass control was at least 95% for all treatments that included pyroxasulfone PRE or VEPOST or pinoxaden VEPOST. Similar control was achieved with pyroxasulfone + carfentrazone except when applied alone PRE at the reduced rate of 35 g ai ha^{-1}. Overall, several successful systems were identified using pyroxasulfone and pyroxasulfone + carfentrazone. Wheat response to these products is influenced by planting depth, application timing, herbicide rate, soil type, and rainfall following application. To reduce crop injury, plant seed to a depth of at least 2.5 cm and closely follow herbicide labels with regard to application rate and timing.

Aquatics

Water temperature and *Eichhornia crassipes* stembase regrowth. John Miskella*, John Madsen; USDA-ARS, Davis, CA (005)

Waterhyacinth (*Eichhornia crassipes*) stem bases were collected from sites in the Sacramento-San Joaquin Delta during the winter of 2016. Any leaves present from the previous year's growth were removed. The stem bases were divided into nine groups of ten. Each group of stem bases was placed in a 38.7L mesocosm at a constant water temperature with a light regime of 14 light/10 dark. Each of the mesocosms were randomly assigned one of three constant water temperatures (5°C, 10°C, and 15°C). The number of leaves per stembase, cumulative length of leaves per stembase, the number of stolons per stembase, and the cumulative length of stolons per stembase were quantified twice per week for each stembase (n=90), beginning at 9 days after collection and continuing until 54 days after collection. Each of these growth characteristics were variable ($P < 0.001$) when analyzed using ANOVA (R. v3.3.2 2016) to detect differences ($P \leq 0.05$) among temperature means 54 days after initiating growth. Mean separations of significant effects were evaluated with Tukey's HSD test ($P \leq 0.05$). For each of these growth characteristics, there was no significant difference between 5°C and 10°C ($P > 0.99$), but there were significant difference between 5°C and 15°C ($P < 0.001$) and 10°C and 15°C ($P < 0.001$). No stolons were produced at 5°C or 10°C, while 10 of the 30 stembases at 15°C produced stolons by 54 days (x=0.43 (0.12) with a mean cumulative length of 6.00 mm (1.71 mm)). Stolon growth is a key driver of dispersal. Daughter plants growing from stolons expand plant mats away from banks, where forces such as tidal movement, wind, water flow, or boats cause portions of mats to break away and disperse. With greatly reduced leaf and stolon production at 5°C and 10°C, *E. crassipes* would disperse at a far lower rate, and would be easier to manage than the stembases exposed to 15°C.

Absorption Rates of 2,4-D Butoxyethyl Ester and 2,4-D Amine by Eurasian Watermilfoil. Kallie Kessler[1], Mirella Ortiz*[1], Scott Nissen[1], William Ratajczyk[2], Ryan Wersel[2]; [1]Colorado State University, Fort Collins, CO, [2]Applied Biochemists - Lonza, Fort Collins, CO (006)

The rate at which herbicides move from the water column into targeted aquatic weeds is important for several reasons. Rapid herbicide absorption would theoretically shorten the concentration exposure time and allow an herbicide to perform well even in areas with high water exchange or as a spot treatment. The herbicide, 2,4-D, is often recommended for Eurasian watermilfoil (Myriophyllum spicatum) management because it is cost effective and selective. The dilemma often faced by applicators is whether to make whole lake treatments at reduced rates or high rate applications as spot treatments. The objective of this project was to determine the rates of 2,4-D absorption as a function of the two most popular formulations, butoxyethyl ester (BEE) and amine, to provide applicators with some research based information about herbicide behavior as a function of formulation. Herbicide absorption was evaluated over a time course of 192 hours using 14C 2,4-D acid mixed with commercial 2,4-D amine or 14C 2,4-D BEE mixed with cold herbicide both at a rate of 1 µg mL-1. The amine formulation of 2,4-D showed a near linear increase in absorption without reaching maximum 192 hours after treatment (HAT), while 2,4-D BEE reached maximum absorption in the first 6 HAT. Herbicide translocation to milfoil roots was very limited for both formulations. These data suggest that in absence of photo-degradation, 2,4-D BEE is well suited for treating areas with high water exchange and for spot treatment because of rapid absorption. Eurasian watermilfoil treated with 2,4-D amine had slower absorption, but given enough time actually accumulated more herbicide.

Efficacy of herbicides for managing Egeria: Mesocosm and field trials. John D. Madsen*[1], Kurt Getsinger[2], Guy B. Kyser[3]; [1]USDA ARS, Davis, CA, [2]USAERDC, Vicksburg, MS, [3]University of California, Davis, CA (007)

Egeria (*Egeria densa*) is the most common submersed aquatic weed in the Sacramento / San Joaquin River Delta of California. The herbicide currently used for management is fluridone, which is effective but requires repeated treatments to maintain efficacy due to tidal water exchange. We performed two studies to examine management of egeria with herbicides: a mesocosm trial of alternatives, and a field study of operational efficacy. The mesocosm trial was performed at the USDA ARS Aquatic Weed Lab, in Davis, CA. Our mesocosm consists of 48 tanks, each with a capacity of 160 liters. Four pots were planted per tank with egeria, and tanks treated four weeks after planting. Four tanks were harvested before treatment. All treatments were replicated four times. Our treatments were an untreated reference, bispyribac sodium (45 ppb), carfentrazone ethyl (200 ppb), copper (1000 ppb), diquat (390 ppb), both the potassium and amine formulations of endothall (5000 ppb), flumioxazin (400 ppb), fluridone (60 ppb), imazamox (500 ppb), and penoxsulam (60 ppb). Treatments were static for eight weeks, at which time the tanks were drained and plants harvested. Visual observations indicated that the copper, diquat, and amine salt formulation of endothall were most effective. In the second study, we followed six treated and six untreated plots of egeria in the Delta, collecting thirty point intercept samples per plot and ten biomass samples per plot, in April, July, and September of 2016. At some locations, management maintained plant diversity while at other locations, egeria was the only submersed plant that was surviving.

Project 1. Weeds of Range and Natural Area

Quantifying Shrub Canopy Interception of Two Imazapic Formulations and Impacts on Downy Brome Biomass. Clay W. Wood*[1], Brian A. Mealor[2]; [1]University of Wyoming, Laramie, WY, [2]University of Wyoming, Sheridan, WY (008)

Herbicides, commonly imazapic, are widely used for downy brome (*Bromus tectorum*) control on western U.S. rangelands. Interception by shrub canopies may reduce the amount of herbicide reaching the soil surface or target species. The objective of this research is to compare the efficacy of a granular formulation of imazapic to the widely-used liquid formulation for downy brome control beneath existing shrub canopies. We aerially applied both formulations of imazapic at 123 g ai·ha^{-1} for the liquid formulation and at 135 g ai·ha^{-1} for the granular formulation at two field sites (Saratoga and Pinedale, Wyoming) in 2015 with an untreated check at each site. In 2016, we collected downy brome biomass beneath shrub canopies and within interspaces between shrubs at both sites. No differences were detected between downy brome biomass beneath shrubs or in interspaces one year post-treatment at Saratoga (p=0.68) or Pinedale (p=0.78). Herbicide treatment was the only factor affecting downy brome biomass at Saratoga (p<0.0001) and Pinedale (p=0.0483). At Saratoga, both imazapic formulations provided similar reductions in downy brome biomass compared to the check, but at Pinedale, the liquid formulation reduced downy brome biomass more than the granular. To directly quantify herbicide reaching the soil surface, we used water sensitive paper for liquid imazapic and 2.37 liter buckets for granular imazapic to determine coverage of each formulation at two additional field sites (Hyattville and Sheridan) during aerial herbicide applications in 2016. Liquid imazapic coverage (%) was significantly greater in interspaces than under shrubs at Hyattville (p<0.0001) and Sheridan (p=0.0005). Granular imazapic weight (g ha^{-1}) was not different under shrubs or within interspaces at both Hyattville (p=0.77) and Sheridan (p=0.72). Due to differences in application equipment and sites, downy brome biomass will be sampled under shrubs and within interspaces at all four field sites in 2017 to determine if similar results are achieved.

Large Scale Control of Invasive Weeds and Response of Native Species to Indaziflam or Indaziflam Tank Mixes. James R. Sebastian*[1], Derek Sebastian[2], Harry Quicke[3], Steve Sauer[4]; [1]Boulder County Open Space, Loveland, CO, [2]Colorado State University, Fort Collins, CO, [3]Bayer CropScience, Windsor, CO, [4]Boulder County Open Space, Longmont, CO (009)

Invasive species management on non-crop and rangeland remains a constant challenge throughout many regions of the US. While there are over 300 rangeland weeds, downy brome (*Bromus tectorum* L.), Dalmatian toadflax (*Linaria dalmatica*), musk thistle (*Carduus nutans*), Scotch thistle (*Onopordum acanthium*), diffuse knapweed (*Centaurea* diffusa), and moth mullein (*Verbascum blattaria*) have emerged as the most invasive and problematic on Boulder County Open Space properties. Downy brome, infesting over 22 million hectares in the US, is a competitive winter annual grass that is considered one of the most problematic invasive species on western rangelands. Downy brome germinates in the fall and early spring, exploiting moisture and nutrients before native plant communities begin active growth in the spring. Downy brome seeds are tolerant to temperature and moisture stress and can remain viable for up to 5 years. While glyphosate, imazapic, and rimsulfuron are currently recommended for annual grass control, they provide inconsistent control or injury to desirable perennial species. In addition, Dalmatian toadflax, musk thistle, moth mullein, and diffuse knapweed infest over 2.8 million ha alone, and are all Colorado Noxious Weed List B species (defined as plants whose continued spread should be stopped). The increasing spread of biennial species is a result of their adaptability, life cycle, and prolific seed production. Many commonly used herbicides lack residual seedling control resulting in rapid re-establishment. Indaziflam (Esplanade®, Bayer CropScience) has been adopted by many land managers throughout Colorado with a new open space and natural areas label. Field studies at Colorado State University (CSU) demonstrated that indaziflam provides superior long-term downy brome control (3+ years) with no documented injury to native perennial species. Indaziflam is a root inhibiting herbicide. This allows for increased safety on desirable perennial plants that have roots below the layer where the herbicide is active. Indaziflam has excellent preemergence activity on many grass and broadleaf weeds and has several attributes that make it an ideal candidate to control weeds that reproduce primarily by seed production, 1) long soil-residual activity and 2) no documented injury to established perennial grasses, forbs, and shrubs. Two large-scale experiments were initiated in the spring of 2016 in collaboration with CSU, to evaluate the efficacy of currently recommended herbicides alone and in combination with indaziflam for restoring open space properties infested with invasive annual grass and broadleaf weeds. Aminocyclopyrachlor and picloram were applied alone and in combination with indaziflam to determine if indaziflam tank-mixes extend the duration of annual, biennial, and perennial invasive weed control by eliminating re-establishment from the soil seed bank. All herbicide treatments were successful at controlling 90 to 99% of weeds, with common mullein appearing in low densities in all treatments. Straight indaziflam and all indaziflam tank mixes resulted in 100% downy brome control the first growing season after treatment. All tank-mix combinations with indaziflam provided an increase in weed control as compared to treatments without indaziflam. Straight indaziflam did not injure any native grasses or forbs, resulting in a significant increase in species richness compared to the non-treated control. Indaziflam tank mixes did not reduce species richness. All treatments significantly increased perennial grass biomass compared to the non-treated control. In 2017, visual control and cover estimates and biomass harvests will provide further evidence for the utility of Esplanade on Boulder County Open Space properties for reducing annual and biennial weed re-establishment occurring from seed. This research could ultimately provide new long-term control options for controlling annual and biennial weeds on Boulder County properties and other counties throughout the western US.

Implications of Drought and a Soil Amendment for Restoration of Cheatgrass-Infested Rangelands. Dirk V. Baker*[1], Magda Garbowski[2], Cynthia S. Brown[2], Danielle Johnston[3], Stuart P. Hardegree[4], Meagan E. Schipanski[2]; [1]Campbell Scientific, Inc, Logan, UT, [2]Colorado State University, Fort Collins, CO, [3]Colorado Parks and Wildlife, Grand Junction, CO, [4]USDA Agricultural Research Service, Boise, ID (010)

Arid rangelands are vulnerable to degradation due to disturbance and invasive species such as cheatgrass. Variable precipitation, drought, and a changing climate further complicate restoration efforts. With their ability to absorb moisture when it is abundant and slowly release it, super-absorbent polymers (SAPs) may be used as a soil amendment to increase water-holding capacity of soil and improve establishment of seeded species for restoration. We tested the effects of SAPs (added or not), drought (ambient or reduced 66%), and cheatgrass (added or not) on soil moisture and seeded species establishment at two sites in Colorado, USA: one in Larimer County (east slope) and one in San Miguel County (west slope). We collected seedling density data as well as continuous soil moisture and temperature data at 5 and 30 cm depths, precipitation, PAR, air temperature, humidity and wind. For these initial analyses we focused on the change in soil moisture after rain events and seedling densities at three time points during the first growing season. The presence of SAPs had no significant effect on the magnitude of the change in soil moisture after a rain event thought it did interact with both drought and cheatgrass at 30cm on the eastern slope and 5cm on the western slope. The effect at 30cm on the eastern slope was small and may not be important. At the western slope site, there was less change in soil moisture when both cheatgrass and SAPs were added under ambient precipitation. Not surprisingly, both drought and cheatgrass decreased the magnitude of soil moisture change. However, the effect of cheatgrass on change in soil moisture was less consistent and depended on drought, SAPs, or both. Cheatgrass did not establish well at the eastern slope site, so there was little effect observed on soil moisture or seeded species. SAPs increased seeded species establishment at the eastern slope site, but not at the western slope site where cheatgrass had a greater effect. These results contrast with previous studies that demonstrated improved establishment under decreased moisture when SAPs were added. This may suggest a minimum threshold below which SAPs lose their effectiveness. This analysis only looked at the magnitude of the change in soil moisture; next steps include examining aspects of the timing (time-to-peak, duration) of this change. Future work also includes the interaction of SAPs with soil type as well as continued monitoring of soil and plant responses for two additional growing seasons. Results from this and subsequent studies may help managers to determine when and where amendments like SAPs can be beneficial.

Developing and Evaluating a Rush Skeletonweed Dispersal and Habitat Suitability Model for Northern Utah. Heather E. Olsen[1], Corey V. Ransom*[1], Larry W. Lass[2], Timothy Prather[2], Simon Wang[1]; [1]Utah State University, Logan, UT, [2]University of Idaho, Moscow, ID (011)

Rush skeletonweed (*Chondrilla juncea*), an invasive perennial weed infests millions of acres in the west. It is a recent invader in Northern Utah, and a recent addition to the Utah noxious weed list. It reproduces both vegetatively and sexually, with wind dispersed seeds responsible for short- and long-distance spread. The University of Idaho has developed a predictive model for habitat suitability and wind dispersal predictability for the Salmon River Canyon in Idaho. These models were evaluated for applicability to predict susceptibility to rush skeletonweed invasion in Northern Utah, and identify areas to search for new infestations. High resolution NAIP imagery, a Utah soils map, and Utah wind data (wind speed and direction) were used to train the existing model for the Northern Utah location. Rush skeletonweed infestation data collected by Box Elder and Cache county weed and pest crews, as well as Utah State University mapping crews from 2012-2015 was used to validate the model. These known locations of rush skeletonweed showed the susceptibility model omitted areas of low vegetation, so a second model was trained on areas missed by the first model. The results were merged and clustered into 5 groups: 0 to 20%, 20 to 40%, 40 to 60%, 60 to 85%, and 85 to 100% susceptibility. Rush skeletonweed infestations detected in 2016 were overlaid across the model in ArcMap and were found to occur in all of the predicted susceptibility areas, with the highest number of infestations and total acreage occurring in the moderately high susceptibility areas (60 to 85%). Additional on-the-ground searches will occur in 2017 to evaluate the wind dispersal model in conjunction with the habitat suitability model in identifying new infestations.

Comparing Residual Herbicides for Annual Grass Control. Natalie Fronk*, Corey V. Ransom, Heather E. Olsen; Utah State University, Logan, UT (012)

Indaziflam is a relatively new alkylazine herbicide labeled for weedy broadleaf and grass management in orchards, vineyards, commercial turf, roadsides, and non-grazed range and forest. However, it is not currently labeled for grazed rangeland and pasture. Recent studies have found indaziflam to be an effective herbicide on rangeland annual grasses such as downy brome and superior to other annual grass herbicides such as imazapic, rimsulfuron, and glyphosate (Sebastion et al. 2016). The purpose of this study was to compare effects of combinations of indaziflam with various herbicides, including propoxycarbozone, glyphosate, imazapic, and rimsulfuron on the winter annual grasses medusahead (*Taeniatherum caput-medusae),* downy brome (*Bromus tectorum)*, and Japanese Brome (*Bromus japonicus)*. Some treatments were evaluated at both preemergence and postemergence application timings. Studies were established at one brome site and one medusahead infested site in Northern Utah. Treatments were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 234 l/ha at 276 kPa pressure. Fall applications were made in November of 2015 and spring applications in April of 2016. Injury and annual grass control were evaluated visually and cover data was collected utilizing point-line transects. Propoxycarbozone provided minimal control of Japanese brome and medusahead, and cover of both species was not different from the untreated control by fall 2016 in both trials. Glyphosate and imazapic provided moderate control in early summer but had high covers of winter annual grass by the fall. Imazapic applications rates were likely too low for the higher rainfall experienced in the treated area. For the treatments applied both fall and spring, spring applications tended to damage desirable grasses more than fall applications, with spring applications of rimsulfuron alone and rimsulfuron with indaziflam causing among the highest desirable grass injury (55 to 94%). Of the fall applications rimsulfuron and indaziflam combinations caused the most damage to desirable grasses (81 to 93%). However, desirable grass cover in October 2016 was not different among treatments in the brome trial. In November, desirable grass cover was greater than the untreated for all treatments in the medusahead trial with the exception of propoxycarbazone alone at both application timings and rimsulfuron plus indaziflam applied in the spring. In October, treatments containing indaziflam had among the least Japanese brome cover. Likewise, all treatments containing indaziflam had among the least medusahead cover at the November evaluation. While some of the treatments evaluated had very high levels of grass injury, fall grass cover was not negatively affected. The long-term suppression of annual grasses with indaziflam, with transitory injury to perennial grasses, provides an option for protecting and reclaiming perennial grass stands from annual grass invasion.

Controlling Japanese Brome During Prairie Restoration in North Dakota. Caleb Dalley*, Daniel Guimaraes Abe; NDSU, Hettinger, ND (013)

Japanese brome is an invasive winter annual grass weed that often impedes reclamation efforts in grasslands in North Dakota, outcompeting desirable forage species and thereby reducing biodiversity. An experiment was conducted in southwest North Dakota to evaluate herbicides and application timing for Japanese brome control during grassland restoration and to measure impacts on grass and forb production. The area was naturally infested with Japanese brome that had become established over years. The site had been planted with a native plant seed mixture containing five native grasses and five native forbs in the fall of 2012. There were two POST application times; six herbicides treatments were applied in fall 2015, and three herbicide treatments were applied in spring 2016. Japanese brome was controlled over 95% 3 weeks after spring treatment (WAST) and over 98% 5 WAST with fall applications of sulfosulfuron, with no differences in control due to rate. Fall application of imazapic controlled Japanese brome over 96% 5 WAST and control was similar with and without paraquat. Fall application of flumioxazin + pyroxasulfone provided poor control of Japanese brome. Total forage biomass was determined on July 18-19 by collecting forage samples from each plot. Fresh and dry weights of grass and forbs biomass were recorded. Forage yield increased with fall application of sulfosulfuron, with yield increasing as rates increased. Imazapic increased forage yield with and without paraquat. Spring application of sulfosulfuron and paraquat did not increase forage yield. Spring application was less effective than fall application for controlling Japanese brome and did not result in increased growth of desired grasses and forbs. For rangeland sites infested with Japanese brome, a late-fall application of imazapic or sulfosulfuron should provide a benefit of Japanese brome control and increased productivity of desired forages.

Project 2: Weeds of Horticultural Crops

Herbicidal Properties of Mustard (Sinapis alba) Meal Compounds and Extract on Powell Amaranth and Green Foxtail. Rick A. Boydston*[1], Matthew J. Morra[2], Ina Popova[2]; [1]USDA-ARS, Prosser, WA, [2]University of Idaho, Moscow, ID (014)

The development of alternative, economically sound methods of weed control is a priority due to a rise in weed resistance and the increased demand for organic crops. Seed meal from yellow mustard (*Sinapis alba* L.) is a potential tool for controlling weeds as a consequence of contained glucosinolate substrates that are enzymatically hydrolyzed by myrosinase to produce a variety of biologically active products. However, there are challenges associated with the use of mustard seed meals as herbicides including batch-to-batch variability, cost and logistics of transportation, storage, and application of large quantities of mustard meal required for weed control. To overcome these challenges, glucosinolate-containing extracts (using 30% ethanol) from *S. alba* seed meal were used as a source of potential biopesticidal hydrolysis products including potassium thiocyanate (SCN^-), 4-hydroxybenzyl alcohol (4-OH), and 4-hydroxyphenylacetonitrile (nitrile). These compounds and mustard seed meal extract were tested for herbicidal activity when applied in aqueous solutions both preemergence (PRE) and postemergence (POST) to Powell amaranth (*Amaranthus powellii*) and green foxtail (*Setaria viridis*) planted in a loamy sand soil in greenhouse trials. Rates tested of SCN^-, 4-OH, and nitrile corresponded to the relative amount of each present in mustard seed meal extract. Pigweed seedlings were 3 to 4 cm tall with 3 leaves and green foxtail were 2 to 4 cm tall with 3 leaves at the time of postemergence applications. When applied PRE or POST, SCN^- and seed meal extract solutions were the most active compounds on both weed species. SCN^- and seed meal extract applied PRE reduced the number of Powell amaranth and green foxtail plants per pot, final plant height, and plant dry weight at 3 weeks after planting. Herbicidal activity increased as rate increased. The highest rate tested of SCN^- at 4.5 kg ha^{-1} controlled Powell amaranth 98% and green foxtail 84%. The highest rate of mustard extract at 94 kg ha^{-1} applied PRE controlled Powell amaranth 97% with a 96% reduction in dry weight and controlled green foxtail 82% with a 76% reduction in dry weight. SCN^- applied POST at 4.5 kg ha^{-1}, controlled Powell amaranth 97% and green foxtail 71% at 14 days after treatment (DAT). Mustard meal extract applied POST at 94 kg ha^{-1} controlled Powell amaranth only 46% with an 82% reduction in dry weight, and controlled green foxtail 23% with a 55% reduction in dry weight at 14 DAT. Little or no herbicidal activity was observed on both weed species following PRE or POST application of 4-OH from 1.4 to 5.8 kg ha^{-1} or nitrile applied PRE from 0.4 to 1.6 kg ha^{-1}. Nitrile applied POST at 1.6 kg ha^{-1}caused minor epinasty on leaves of Powell amaranth and minor leaf tip necrosis on green foxtail. These results suggest that the herbicidal activity observed in solutions of mustard seed meal extract on these weeds can be attributed primarily to the SCN^- content.

Managing Red Potato Blemishes with 2,4-D. Andrew Robinson*, Eric Brandvik; North Dakota State University, Fargo, ND (015)

Abstract not available

Biology and Control of Broadleaf Dock. Wiharti O. Purba*[1], Lisa W. DeVetter[1], Chris Benedict[2], Ian C. Burke[3], Timothy W. Miller[1]; [1]Washington State University, Mount Vernon, WA, [2]WSU Whatcom Extension Center, Bellingham, WA, [3]Washington State University, Pullman, WA (016)

With its high regenerative capacity, broadleaf dock (*Rumex obtusifolius*) can cause significant reduction in yield and quality of crops and is particularly troublesome in Pacific Northwest blueberry and red raspberry production. Efficacy of herbicides commonly used in berry production has not been reported, however. Therefore, two field herbicide trials were established in a pasture highly infested with broadleaf dock at the Washington State University Northwestern Washington Research and Extension Center near Mount Vernon, Washington, and seed germination trials were initiated. In the first trial, sixteen herbicides were applied May 23, 2016 to bolting broadleaf dock and, in a second trial, eighteen herbicides were applied October 28, 2016 to broadleaf dock regrowth approximately one month after mowing. Plots in both trials measured 2.44 by 9.14 m and were arranged in a randomized complete block design with four replicates. In the first trial, glyphosate at 7.48 l/ha resulted in the lowest broadleaf dock biomass (8.4 g/m^2) at 8 weeks after treatment (WAT), while Sinbar at 3.36 kg/ha resulted in biomass of 16.9 g/m^2, compared to non-treated broadleaf dock biomass of 147.02 g/m^2. In the second trial, visual broadleaf dock control at 3 WAT was 20% with glyphosate at 7.48 l/ha and 10% with norflurazon at 5.6 kg/ha. In preliminary tests, broadleaf dock seed germination was greater at 20 C than at 15 C or 25 C, indicating that control of broadleaf dock seedlings could be optimized if preemergence treatments were applied prior to the summer season. Initial seed germination data from seed collected from surviving broadleaf dock plants in the first trial indicate that herbicide clopyralid may reduce germinability of seed and slow the spread of the weed in berry fields.

Project 3. Weeds of Agronomic Crops

The Effect of White Chinese Geese on Weed Densities in Certified Organic Quinoa Production. Kristofor C. Ludvigson*, Kevin M. Murphy; Washington State University, Pullman, WA (017)

Like many other organic crops, quinoa production has created a need for growers to utilize alternative methods of weed control. One alternative is the use of animals as biological agents capable of reducing weed populations. The objective of this study was to evaluate the positive and negative effects of White Chinese geese within an organic quinoa production system. For six weeks during the 2015 and 2016 growing seasons, two groups of 11 geese were placed into treatment areas to graze for 12 hours per day, either two days per week or five days per week. Two control treatments were also included; one receiving no weeding and another kept weed free via hand cultivation. These four treatments were contained within a split-plot completely randomized design and included two quinoa varieties (Titicaca & Red Head) adapted to western Washington growing conditions. We tested the effect of the geese on weed density, quinoa seed yield, and agronomic characteristics of quinoa (e.g. plant height, flowering and lodging). Additionally, we evaluated the reliability of the geese in consuming only weeds, and their ability to work within Good Agricultural Practices (GAPs), all under field conditions on the Olympic Peninsula of Washington State. Reductions in grass and broadleaf weed species were observed, with geese primarily consuming weeds and leaving quinoa plants undamaged. Preliminary results show quinoa seed yield in the two-day treatment was slightly lower than that of the unweeded control, whereas seed yield in the five-day treatment was slightly lower than that in the completely weeded control. Plant development followed a similar pattern across treatments. These results illustrate the possibility that White Chinese geese could be utilized to successfully control weeds and improve the soil nutrient content of crop land used for quinoa, all while working within the rules of certified organic production.

Evaluating Weed Control Options for Sweet White Lupine (*Lupinus alba*) in Wyoming. Gustavo M. Sbatella*; University of Wyoming, Powell, WY (018)

There is an increasing interest in planting white sweet lupine in the US, and with it an increasing demand for certified lupine seed. Environmental conditions in northwestern Wyoming are optimal for crop seed production. In order for farmers to add a new crop to their rotations effective weed control programs are critical. Currently there are few herbicides labeled for use in white sweet lupine, and some impose serious cropping restrictions for Wyoming growers. Field studies were conducted near Powell and Ralston WY with the objective to evaluate efficacy and crop safety of herbicides applied pre-plant incorporated (PPI) for weed control in sweet white lupine grown under furrow irrigation. The tested active ingredients included S-metolachlor (Dual II Magnum®), ethalfluralin (Sonalan®), dimethenamid-p (Outlook®), and trifluralin (Treflan®). No signs of visual crop injury were observed with any of the PPI treatments, and further plant stand counts recorded showed no differences between treatments. All PPI treatments reduced weed pressure when compared to the non-treated checks, but differences in efficacy was observed between treatments at each location. Despite the early weed control provided by the PPI, weed pressure increased during the growing season requiring the area to be hand weeded twice. Sweet white lupine is a novel crop in the area and there are no records available in regards to its potential yield. Yields obtained from the hand weeded treatment indicate that 1000 lb. /a. is a yield obtainable in the area. Results from these studies suggest that several active ingredients have the potential to be used for PRE control in lupine. Nevertheless, these treatments will not provide season long weed control.

Chickpea Tolerance and Broadleaf Weed Control with Pyridate. Rachel J. Zuger*, Ian C. Burke, Amber L. Hauvermale, Jeanette A. Rodriguez, Lindsay E. Koby, Henry C. Wetzel, Drew J. Lyon; Washington State University, Pullman, WA (019)

Postemergence (POST) broadleaf weed control is not currently an option for chickpea growers in the PNW due to the lack of POST broadleaf herbicides registered for use. Preemergence options exist but activity is dependent on spring precipitation for activation, and as a consequence control can be variable. Pyridate, a photosystem II inhibitor, is a potential POST applied herbicide for chickpea, where it was formerly registered. In 2016, four trials were conducted to evaluate chickpea tolerance and POST broadleaf weed control for pyridate. Treatments of pyridate at 1050 and 2100 g ai ha^{-1}, with and without a nonionic surfactant (0.25% v v^{-1}, NIS), were applied to chickpeas at the 5 to 10 cm and 20 to 25 cm growth stages under three different environmental conditions; dryland weedy, dryland weed-free, and irrigated weed-free. An additional study was conducted with chickpea varieties Royal, Sierra, Billy, and Sawyer, to observe varietal response to pyridate at the two aforementioned treatment concentrations with NIS (0.25% v v^{-1}). Results from the weedy study determined treatments of pyridate applied at either herbicide timing controlled common lambsquarters, resulting in significantly higher chickpea yields. Yields were greatest in treatments with the higher rate of pyridate (2100 g ai ha^{-1}) with and without NIS applied at the later application timing (2400 and 2265 kg ha^{-1}, respectively), while the weedy check yielded approximately half (1038 kg ha^{-1}). The only exception was when pyridate was tank-mixed with clethodim (280 g ai ha^{-1}) and a crop oil concentrate (0.25% v v^{-1}) at the earlier application timing, causing a slight reduction in yield with no crop injury or lack of common lambsquarters control observed. Similar results were observed in the variety trial with significantly greater yield for all varieties treated with either rate of pyridate compared to the weedy nontreated control for each variety. Significant crop injury was observed for chickpea varieties Sierra and Royal although no negative impact on yield was observed. Weed-free studies indicate that chickpeas have tolerance to pyridate with no observed crop injury or significant reductions in yield compared to the nontreated controls. Pyridate appears to be an effective postemergence herbicide for chickpea in the Pacific Northwest.

Application Timing Affects Soil-applied Herbicide Efficacy in Chickpea. Drew J. Lyon*[1], Henry C. Wetzel[1], Rick A. Boydston[2], Joan M. Campell[3]; [1]Washington State University, Pullman, WA, [2]USDA-ARS, Prosser, WA, [3]University of Idaho, Moscow, ID (020)

Chickpeas are an important rotational crop with wheat in eastern Washington and northern Idaho. There are no postemergence herbicide options for broadleaf weed control in chickpea, so growers often rely on preemergence (PRE) applications for broadleaf weed control. However, soil-applied herbicides require adequate rainfall for activity and rainfall after planting is unreliable. The objective of this research was to compare early preplant herbicide applications to PRE applications for broadleaf weed control in chickpea. Field studies were conducted under rainfed conditions near Pullman, WA and Moscow, ID in 2015 and 2016. An irrigated field study was conducted near Prosser, WA in 2016. Flumioxazin (71.4 g ai ha^{-1}), linuron (700 g ai ha^{-1}), metribuzin (280 or 420 g ai ha^{-1} for irrigated and rainfed sites, respectively), and sulfentrazone (280 g ai ha^{-1}) were applied 4 to 6 wk prior to planting, 2 to 3 wk prior to planting, and post-plant PRE. Visual control ratings and weed density measurements were made 4 to 6 wk after planting. Plots were harvested for grain yield and 100-seed weight was determined. Rainfall varied between sites and years and was a significant factor influencing results across sites and years. Application timing had no effect on visual weed control, weed density, crop yield, or seed weight in three of the five field studies. Application timing did affect some results at the Pullman sites in 2015 and 2016, although the effect was not consistent between years. In 2015, visual control of ANTCO was significantly less for linuron and metribuzin treatments applied prior to planting compared to the same herbicides applied PRE. In 2016, visual control of CHEAL was significantly less for all herbicides applied PRE compared to applications made prior to planting. CHEAL density was also significantly greater for all herbicide treatments applied PRE compared to early preplant applications. Differences in weed control were observed between herbicides at all locations and years. Sulfentrazone consistently provided excellent weed control while linuron consistently provided the least control of CHEAL. Although the effect of application timing was not consistent across all field sites and years, our research suggests that flumioxazin and sulfentrazone may be applied up to 6 wk prior to planting with no negative effects on weed control or yield compared to PRE applications.

Performance of Fall and Spring Applied Field Pea Herbicides. Travis R. Orrell*[1], Gail Stratman[2], Cody F. Creech[3]; [1]University of Nebraska, Sidney, NE, [2]FMC, Stromsburg, NE, [3]University of Nebraska, Scottsbluff, NE (021)

Effective early season weed control is necessary in yellow field peas (*Pisum sativum*) because the crop is a poor competitor during early growth stages due to factors such as cold temperatures and wet soils. Making herbicide applications prior to pea emergence is imperative to obtain satisfactory yields. Trials were initiated in 2015 at the University of Nebraska-Lincoln High Plains Ag. Lab near Sidney, NE to evaluate the effects of application timing on weed control and pea yields of using a variety of herbicide treatments. The field pea cultivar DS Admiral was treated with several herbicide regimens on three treatment dates (10-25-15, 3-22-16, and 6-16-16) which represent a fall, preemergence, and postemergence applications. Visual control ratings of downy brome (*Bromus tectorum*), puncture vine (*Tribulus terrestris*), marestail (*Conyza canadensis*), and Russian-thistle (*Salsola tragus*) were recorded throughout the growing season. The plots were direct harvested using a Hege 180 plot research combine, and grain yield was recorded. A sulfentrazone + S-metolachlor fall application provided adequate control of the weeds present and had the greatest yield (2663 kg ha^{-1}) although not different than the sulfentrazone + S-metolachlor spring treatment (2428 kg ha^{-1}) or the fall and spring applied sulfentrazone + carfentrazone treatments (2112, 2213 kg ha^{-1}, respectively). This research demonstrated that fall applied herbicides can be just as effective at controlling weeds in field peas as spring applied herbicides. This can alleviate some of the labor and time constraints that are common for producers in the spring. Continued research aims to identify more effective and economical herbicide regimens to be used for the production of dry field peas in the Nebraska Panhandle.

Winter Canola Tolerance to Clomazone and S-metolachlor. Misha R. Manuchehri*[1], Todd A. Baughman[2], Josh J. Lofton[1]; [1]Oklahoma State University, Stillwater, OK, [2]Oklahoma State University, Ardmore, OK (022)

Currently, there are eight herbicides and five modes of actions labeled for use in winter canola. This list includes herbicides that can be used in Roundup Ready® and Clearfield® systems. As a result of the limited number of products available, absence of preemergence herbicides, and increase in herbicide resistant weeds, weed management in canola is challenging. To assess potential premergence options in Oklahoma winter canola, two field trials were conducted during the 2016-17 field season in Stillwater and Lahoma, OK to evaluate winter canola tolerance to clomazone and *S*-metolachlor. Following planting, clomazone and *S*-metolachlor were applied alone or in combination. Clomazone was applied at 92, 105, 118, or 184 g ai ha^{-1} while *S*-metolachlor was applied at 233, 267, 300, or 467 g ai ha^{-1}. Total percent crop injury was recorded 3, 5, and 8 weeks after planting (WAP). Three WAP in Stillwater, all treatments that included clomazone, regardless of herbicide rate, injured canola 11 to 50%. By 5 WAP, canola injury was 11 to 36% for all treatments with the exception of clomazone applied at 92 g ai ha^{-1} alone or in a tank mixture with S-metolachlor at 233 g ai $ha^{-1.}$ For these treatments, no injury was observed. In Lahoma, canola injury was less than 4% for all treatments with the greatest injury occurring at the highest rate of clomazone applied alone or in combination with S-metolachlor at 467 g ai ha^{-1}. Five

WAP, crop injury was 2% or less for all treatments. Increased canola injury due to clomazone at the Stillwater site was likely due to colder temperatures that followed a later planting date. *S*-metolachlor applied alone, regardless of location or application rate, resulted in less tan 1% canola injury.

Volunteer Persistence of Canola, Radish, and Turnip Under Different Tillage Regimes. Gabriel D. Flick*, Carol Mallory-Smith; Oregon State University, Corvallis, OR (023)

In Oregon's Willamette Valley, a desire to raise canola (*Brassica napus*) is challenging a decade-long moratorium and causing concerns about its coexistence with *Brassica* fresh vegetable seed production. Concerns raised include increased pests, gene flow and seed contamination. Anecdotal differences in persistence and volunteer potential among crops belonging to the *Brassicaceae* family have been noted by growers. A field trial was initiated to determine if differences in seed persistence exist among three widely grown *Brassicaceae* crops and how tillage affects seed bank longevity. Radish (*Raphanus sativus*), turnip (*B. rapa*), and canola (*B. napus*) seed were spread on plots at rates equal to harvest losses, 2250, 3000, and 2700 per m^2, respectively. Three treatments, deep tillage, shallow tillage, and no tillage, were performed and repeated yearly for three years. During the year, emerged plants were counted. A non-residual burndown herbicide was applied immediately after each count to prevent seed production in the plots. Excluding the initial flush of volunteers, emergence in deep tilled plots increased for all three crops over the three years. Radish emergence was greater in both deep tillage and shallow tillage plots. After the initial flush of volunteers, almost no canola or turnip emerged in the no tillage treatment. Radish seed appears to be more persistent compared to canola or turnip seed. Preliminary data indicate that the no tillage treatment was most effective at depleting the seed bank and deep tillage should be avoided if seed persistence is of concern.

Different Genes Control Dicamba-Resistance in Kochia from Colorado and Kansas. Junjun Ou*[1], Dean Pettinga[2], Philip Stahlman[3], Philip Westra[4], Todd A. Gaines[2], Mithila Jugulam[1]; [1]Kansas State University, Manhattan, KS, [2]Colorado State University, Fort Collins, CO, [3]Kansas State University, Hays, KS, [4]Colorado State University, Ft. Collins, CO (024)

Abstract not available

Characterizing the Phenotypic Response to Fluroxypyr in *Kochia scoparia*. Olivia E. Todd*[1], Dean Pettinga[2], Eric Westra[2], Phil Westra[2], Todd Gaines[2]; [1]Colorado State University, Fort Collins, CO, [2]Colorado State University, Fort Collins, CO (025)

Fluroxypyr is a group O (4) herbicide. Herbicides in the synthetic auxin group mimic indole acetic acid (IAA), an auxinic plant hormone that is integral to gene expression regulation. Among cases of herbicide resistance in weeds to synthetic auxins, there have been only five reported cases of fluroxypyr resistance and with four different species. Several phenotypic responses following fluroxypyr treatment will be measured in a putative fluroxypyr-resistant line of *Kochia scoparia* from eastern Colorado (CO-R). This line was collected from the field and subjected to one generation of fluroxypyr selection in the greenhouse. The progeny of this selection survived the label rate (1X = 156.9 g fluroxypyr/ha), and had an ED50 of 147 g/ha for change in height after treatment, and an ED50 of 387 g/ha for visual rating. A susceptible line (CO-S) had an ED50 of 18 g/ha for change in height after treatment and an ED50 of 59 g/ha for visual rating. Shoot gravitropism measurements are expected to show CO-R reorienting towards vertical at a slower rate than CO-S (degrees per hour) due to reduced sensitivity to naturally produced auxin. Root gravitropism experiments are expected to show faster growth (degrees per hour) in CO-S when compared to CO-R due to auxin binding or auxin signal transduction pathways being impaired. Root growth inhibition assays with the CO-R line are expected to show less sensitivity to media containing the equivalent 2X fluroxypyr rate than the CO-S line due to whole-plant resistance. These experiments will characterize the basic physiology of the putative fluroxypyr-resistance in *K. scoparia* from eastern Colorado.

Integrating Crop Rotation and Herbicide Programs to Control Kochia Prior to Sugarbeet in Western Nebraska. Clint W. Beiermann*[1], Nevin C. Lawrence[2]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Scottsbluff, NE (026)

Kochia *(Kochia scoparia*) is a competitive and problematic weed in sugarbeet. With few effective herbicides registered for control of kochia, sugarbeet production relies heavily on glyphosate for post emergence weed control. Glyphosate-resistant kochia have become prevalent within the High Plains sugarbeet production region. Integration of multiple-year cultural and herbicide management strategies may become necessary to control glyphosate-resistant kochia in sugarbeet. Different herbicide combinations in three common rotational crops, corn, dry bean, and a small grain cereal, were evaluated to determine which crop and herbicide combination would be the most effective at suppressing kochia the year before sugarbeet are planted. Small grain herbicide treatments, all applied POST, included pyrasulfotole plus bromoxynil, pyrasulfotole plus bromoxynil plus MCPA, and pyrasulfotole plus bromoxynil plus fluroxypyr. Dry bean herbicide treatments included EPTC plus dimethenamid-P applied PRE, EPTC plus dimethenamid-P followed by bentazon applied POST, and EPTC plus dimethenamid-P followed by two applications of bentazon. Corn herbicide treatments included glyphosate plus dicamba applied POST followed by glyphosate, glyphosate plus saflufenacil plus dimethenamid-P applied PRE followed by glyphosate plus dicamba applied POST, and 2,4-D plus flumioxazin applied PRE followed by rimsulfuron plus thifensulfuron-methyl applied POST. Both the small grain cereal and dry bean were effective at suppressing kochia regardless of herbicide treatment. In corn the glyphosate plus dicamba followed by glyphosate and the glyphosate plus saflufenacil plus dimethenamid-P followed by glyphosate plus dicamba treatments were the most effective at controlling kochia. Sugarbeet will be planted in the following season across all treatments to evaluate multi-year herbicide treatments.

Cross Resistance to Clopyralid and ALS Inhibiters in Mayweed Chamomile (*Anthemis cotula*). Jeanette A. Rodriguez*, Rachel J. Zuger, Amber L. Hauvermale, Ian C. Burke; Washington State University, Pullman, WA (027)

Mayweed chamomile (*Anthemis cotula L.)* is not currently known to be resistant to synthetic auxin herbicides. Three mayweed biotypes with suspected resistance to clopyralid and ALS inhibiting herbicides were tested. The three biotypes, Dayton1 (D1), Dayton2 (D2), and Colfax (C), and a susceptible comparison biotype were treated with increasing doses of clopyralid to determine the level of resistance in the first study, and with an array of herbicides with different modes of action in the second study. The two studies were arranged in a completely randomized design and were repeated in time. In each study, visual injury, survival, fresh and dry weights were recorded 3 weeks after treatment. Results from the dose response confirmed resistance to clopyralid in all three biotypes compared to the susceptible biotype. Biotype D1 (GD_{50}: 285 g ae ha^{-1}) was 1.65 time more resistant, D2 (GD_{50}: 4034 g ae ha^{-1}) was 23.32 time more resistant, and C (GD_{50}: 16800 g ae ha^{-1}) was 97.11 times more resistant than the susceptible (GD_{50}:173 g ae ha^{-1}). Biotype C had 80% survival at the highest rate applied, although 55% injury was observed indicating some phytotoxic activity. Resistance to multiple herbicides was identified in biotypes D1, D2, and C. Biotype D1 was resistant to 1 of 5 synthetic auxins, D2 was resistant to 4 out of 5, and C was resistant to 3 out of the 5 synthetic auxins applied. All three biotypes were resistant to sulfonylurea herbicides. Future work will attempt to identify mechanisms of resistance to clopyralid.

Comprehensive Crop Tolerance and Weed Efficacy of Halauxifen-methyl + Florasulam in Winter Cereals throughout the Central and Eastern US. Daniel Chad Cummings*[1], Roger Gast[2]; [1]Dow AgroSciences LLC, Perry, OK, [2]Dow AgroSciences, Indianapolis, IN (028)

Arylex™ active (halauxifen methyl) a new active ingredient from Dow AgroSciences, is a novel synthetic auxin (WSSA group 4) herbicide from the new "arylpicolinate" chemical class being developed for the U.S. and major cereal markets around the globe. The first U.S. product, Quelex™ herbicide is a premix with florasulam, with a use rate of 0.75 oz pr/acre (halauxifen methyl 5.25 g ae/ha + florasulam 5.25 g ai/ha) and is registered in wheat (including durum), barley and triticale. Field research was conducted from 2012 to 2015. Quelex was compared to competitive standards when applied alone in water and differing levels of UAN fertilizer, as well as in tank mixes with phenoxy (2,4-D LVE or MCPA LVE) herbicides. Quelex demonstrated similar to or better control of multiple broadleaf species, including henbit, flixweed, marestail, and mustards compared to Finesse (chlorsulfuron + metsulfuron methyl) + MCPA low volatile ester or Harmony Extra SG (thifensulfuron + tribenuron) + 2,4-D low volatile ester. Henbit control was rapid with Quelex, especially when mixed with phenoxy herbicides or UAN fertilizer tank mixes versus the standard treatments. By 6 to 10 WAT, Quelex treatments controlled 23 of 27 weed species; while Quelex + a phenoxy herbicide or UAN and Finesse + MCPA ester controlled almost all weed species. Quelex herbicide with Arylex active will provide cereal growers with an alternative mode of action for many difficult to control broadleaf weeds traditionally targeted by sulfonylurea herbicides. Quelex will allow for superior rotational crop flexibility compared to many competitive standard herbicides.

Liquid Formulations of Thifensulfuron + Fluroxypyr and Thifensulfuron + Fluroxypyr + Metsulfuron with Various Tank Mixtures in Winter Wheat. Amanda L. Koppel*[1], William L. Hatler[2], Ken Carlson[3], Joan M. Campell[4], Edward S. Davis[5], Donald L. Kambitsch[6], Drew Lyon[7], Henry C. Wetzel[7]; [1]DuPont Crop Protection, Richland, WA, [2]DuPont Crop Protection, Boise, ID, [3]DuPont Crop Protection, Johnston, IA, [4]University of Idaho, Moscow, ID, [5]Montana State University, Bozeman, MT, [6]DuPont Crop Protection, Lewiston, ID, [7]Washington State University, Pullman, WA (029)

DuPont liquid herbicides Sentrallas®, thifensulfuron + fluroxypyr, and Travallas™, thifensulfuron + fluroxypyr + metsulfuron, are currently labeled for application rates up to 14 fl oz per acre (nationally) and 12 fl oz per acre (WA/OR/ID only), respectively. To determine efficacy on local weeds of interest, 10 fl oz per acre rates of Sentrallas® and Travallas™ were applied alone or in tank mixtures to weeds in winter wheat as a spring application. Herbicides were applied when wheat was between the 3-leaf stage and jointing, and weeds were less than 4 inches high. Treatments were applied broadcast in 9 different research trials across WA, ID, and MT, and wheat was monitored for crop response to herbicides at approximately 7, 14, and 28 days after application. Efficacy data were collected at approximately 14, 28, and 42 days after application. End-of-season results were pooled between trials, with product efficacy on henbit, catchweed bedstraw, prickly lettuce, mayweed chamomile, Jim Hill mustard, dwarf mallow, tansymustard, and blue mustard evaluated. All tank mix treatments with Sentrallas® or Travallas™, regardless of tank mix partner, provided excellent control (93-100 % control rating) of these weeds. All treatments tested on Jim Hill mustard, dwarf mallow, and tansymustard sp. had 100% weed control on the final evaluation day. All Sentrallas® and Travallas™ tank mixes provided 94-100 % control for henbit, bedstraw, and blue mustard. The average crop response at 43-49 DAT was less than 5% in all treatments, with the exception of tank mixes with Travallas™ + Osprey (6-12%) and Travallas™ + Starane Flex + PowerFlex (7.5%).

Smooth Scouringrush Difficult to Control with Fallow-Applied Herbicides in a Winter Wheat/Spring Wheat/Fallow Rotation. Mark Thorne*[1], Derek Appel[2], Henry C. Wetzel[1], Drew Lyon[1]; [1]Washington State University, Pullman, WA, [2]Washington State University, Davenport, WA (030)

Smooth scouringrush is becoming more prevalent in non-irrigated cropping systems in the Pacific Northwest where direct-seed is replacing conventional tillage. Smooth scouringrush is a deep-rooted perennial that spreads primarily from rhizomes. Herbicide control in non-cropland has been limited to long-residual soil active herbicides and few options are available for control in cropping systems. We compared ten herbicide treatments applied during the fallow phases of a winter wheat/spring wheat/chemical fallow rotation in the intermediate rainfall zone (16 to 20-inch per year) near Reardan, WA. Herbicides were applied prior to seeding winter wheat in 2014 and again following winter wheat harvest in 2015. Spring wheat was grown in 2016. Herbicides were evaluated on density of smooth scouringrush stems in two linear meters of row per plot counted in May and August of 2015 and 2016. Smooth scouringrush density averaged 0.3 stems per meter row where chlorsulfuron was applied in both years compared with 36 stems per meter row in the non-treated checks. When chlorsulfuron was applied only the first year, average density increased from 3 stems per meter row in 2015 to 14 stems per meter row in 2016. Long-term annual use of chlorsulfuron may eliminate smooth scouringrush, but herbicide residual will be a constraint for adding crops other than wheat to the rotation. Herbicides commonly applied in chemical fallow, specifically glyphosate, gave no long-term control. Control of smooth scouringrush in cropland will require integrated and targeted approaches with more effective herbicides and cultural practices.

Evolution of Glyphosate-Resistant Horseweed and Russian thistle in Montana Cereal Production. Prashant Jha*, Vipan Kumar, Shane Leland, Anjani J, Charlemagne A. Lim; Montana State University, Huntley, MT (031)

Glyphosate-resistant (GR) weeds pose a serious threat to no-till, cereal production systems of the Northern Great Plains, including Montana. During summer/fall 2015, seeds of one putative GR Russian thistle (GR-RT) population and one GR horseweed (GR-H) population were collected from wheat-fallow fields in Choteau and McCone counties, MT, respectively. The objectives of this research were to 1) confirm and characterize the levels of glyphosate resistance in these GR populations relative to known glyphosate-susceptible (GS-RT from MT and GS-H from NE, respectively) populations and 2) determine the effectiveness of POST herbicides (labelled in wheat-fallow rotation) for controlling these GR populations. Whole-plant glyphosate dose-response experiments indicated that the GR-RT population exhibited 4.5-fold resistance to glyphosate relative to the GS-RT population on the basis of shoot dry weight response (GR_{50} values). On the basis of percent control ratings (I_{50} values), the GR-H population exhibited 3.1-fold resistance to glyphosate relative to the GS-H population. Among alternative POST herbicides to control GR Russian thistle, bicyclopyrone + bromoxynil, bromoxynil + fluroxypyr, bromoxynil + pyrasulfotole, bromoxynil + MCPA, paraquat alone, paraquat + metribuzin, saflufenacil alone, saflufenacil + 2,4-D, and 2,4-D + bromoxynil + fluroxypyr provided effective control (≥95%) and shoot dry weight reduction (up to 98%) of GR population. In a separate greenhouse study, POST herbicides including bromoxynil + pyrasulfotole, dicamba alone, dicamba + diflufenzopyr + 2,4-D, 2,4-D alone, fluroxypyr + clopyralid + MCPA, glufosinate, paraquate alone, paraquat + metribuzin, saflufenacil, saflufenacil + 2,4-D, thifensulfuron + tribenuron + clopyralid + fluroxypyr provided ≥ 90% control of GR horseweed at 21 d after treatment (DAT). This study confirms the first global case of GR Russian thistle in MT. Occurence of GR horseweed in MT cereal production was also confirmed. Growers should utilize these herbicide programs (based on multiple modes of action, highlighted in this study) to manage GR Russian thistle and horseweed populations in their cereal production fields.

Bicyclopyrone: Major League Weed Control in Minor League Crops. Stephen M. Schraer*[1], Dain E. Bruns[2], Cheryl L. Dunne[1], Gordon D. Vail[1], Monika Saini[1], Stott W. Howard[1]; [1]Syngenta, Greensboro, NC, [2]Syngenta, Greensoro, NC (032)

Bicyclopyrone is a newly registered HPPD-inhibiting active ingredient for control of dicot and some grass weeds. Bicyclopyrone is one of the four active ingredients in Acuron herbicide which was registered for sales in corn in 2015. Syngenta is evaluating the potential for expanding bicyclopyrone use into minor/specialty crops where options for weed control are limited. In 2016, University and Syngenta trials evaluated both PRE and POST bicyclopyrone applications for crop tolerance and weed control in minor crops, including onion, carrot, horseradish, hops, rosemary, sweet potato, timothy, and ornamentals.

Broadleaf Weed Control in Winter Wheat with Bicyclopyrone Plus Bromoxynil. Traci Rauch*, Joan M. Campell; University of Idaho, Moscow, ID (033)

Bicyclopyrone/bromoxynil was recently registered in winter wheat to control broadleaf weeds. Bicyclopyrone is a group 27 herbicide that inhibits 4-hydroxyphenyl-pyruvate dioxygenase (HPPD) and is combined with bromoxynil, group 6 herbicide that inhibits photosystem II. Bicyclopyrone/bromoxynil will be used to control group 2 (acetolactate synthase inhibitor) resistant broadleaf weeds, including mayweed chamomile and prickly lettuce. Studies were conducted in Idaho in spring 2014, 2015, and 2016 in winter wheat to evaluate broadleaf weed control. Bicyclopyrone/bromoxynil was applied at 0.193, 0.225, and 0.256 lb ai/A and compared to standards including: pyrasulfotole/bromoxynil alone or with MCPA ester, fluroxypyr/florasulam, fluroxypyr/clopyralid, and thifensulfuron/tribenuron plus MCPA ester. The experimental design was a randomized complete block with 4 replications and included an untreated check. Crop injury and weed control were evaluated visually where 0% represented no injury or control and 100% represented complete plant death. Grain was harvested at maturity. In 2014, no treatment injured winter wheat. Bicyclopyrone/bromoxynil at all rates and pyrasulfotole/bromoxynil alone or with MCPA ester controlled prickly lettuce 93 to 99% and catchweed bedstraw 83 to 93%. Mayweed chamomile control was better with all rates of bicyclopyrone/bromoxynil compared to the pyrasulfotole/bromoxynil treatments. Grain yield for all treatments, expect pyrasulfotole/bromoxynil plus MCPA ester, was greater than the untreated check. Wheat test weight did not differ among treatments, including the untreated check. In 2015, studies were located at Culdesac and Genesee, Idaho. No treatment injured winter wheat at either location. At Culdesac, bicyclopyrone/bromoxynil at all rates, pyrasulfotole/bromoxynil, and fluroxypyr/florasulam controlled catchweed bedstraw 84 to 93%. Bicyclopyrone/bromoxynil controlled mayweed chamomile 85 to 94%, but mayweed chamomile was not controlled by pyrasulfotole/bromoxynil or fluroxypyr/florasulam (66 and 50%). At Genesee, all bicyclopyrone/bromoxynil rates and pyrasulfotole/bromoxynil controlled common lambsquarters 94 to 99%. Bicyclopyrone/bromoxynil treatments did not control prickly lettuce (42 to 74%). Pyrasulfotole/bromoxynil and fluroxypyr/florasulam controlled prickly lettuce 98%. Grain yield and test weight did not differ among treatments, including the untreated check. In 2016, no treatment visually injured winter wheat. All rates of bicyclopyrone/bromoxynil controlled mayweed chamomile 96 to 99% while pyrasulfotole/bromoxynil did not control mayweed chamomile. Fluroxypyr/clopyralid and fluroxypyr/florasulam controlled mayweed chamomile 94 and 98%, respectively. Grain yield for all treatments was better than fluroxypyr/clopyralid and the untreated check. Fluroxypyr/clopyralid reduced grain yield but wheat injury was not visible during the growing season due to variety variability. Wheat test weight did not differ among treatments, including the untreated check.

Mapping Weeds at Harvest by Optical Sensing of Green Plant Matter in Flowing Grain. Judit Barroso*[1], John D. McCallum[2], Dan S. Long[2]; [1]Oregon State University, Pendleton, OR, [2]ARS-USDA, Pendleton, OR (034)

Kochia (*Kochia scoparia* L.), Russian thistle (*Salsola* ssp.), and prickly lettuce (*Lactuca serriola*) are economically important weeds infesting dryland wheat (*Triticum aestivum* L.) production systems in the western United States. Their late maturing nature means that they may still be green and growing well after the wheat crop is physiologically mature. When the crop is harvested, the weedy plant matter that does not separate will be contained in the grain stream. The objectives of this study were to determine the ability of optical, near infrared (NIR) sensing for detecting green plant matter in flowing grain and assess the potential usefulness of this information for mapping weeds at harvest. An in-line optical sensor with sensitivity in the visible and NIR wavelengths (500-1100 nm) was mounted on the clean grain filling auger of a combine harvester. Spectra of the grain stream were recorded continuously at a rate of 0.33 Hz during harvest of an 18 ac wheat field. All readings were georeferenced using a GPS receiver with 1 m positional accuracy. Chlorophyll of green plant matter was detectable in the red (670 nm) waveband. A map of the chlorophyll signal showed a good relationship (78% agreement on average) with the reference map constructed prior to harvest of the three green weed species. This information on weed distributions at harvest is useful to optimize the post-harvest control of these species by using site-specific herbicide applications. Kochia, Russian thistle, and prickly lettuce produce most of their seeds post-harvest, their control at that time reduces the amount of seeds that, otherwise, would become part of the seed bank.

Cover Crop-Weed Dynamics in Two Contrasting Management Systems in the Northern Great Plains. Jose G. Franco*[1], Kenneth Beamer[2], Greta Gramig[2]; [1]USDA-ARS, Mandan, ND, [2]North Dakota State University, Fargo, ND (035)

The Natural Resources Conservation Service (NRCS) recommends multi-species cover crop cocktails to producers in order to maximize ecosystem service benefits. Some of the benefits cited by NRCS are associated with soil nutrient cycling, water quality, pollinator forage, and weed suppression. Costs associated cover crop cocktails can by high, however, and little is known about the establishment of individual species wtihin these mixtures under altered moisture conditions. Changes in precipitation and temperature patterns in the Northern Great Plains in recent decades indicate earlier and wetter springs and a longer growing season, and climate change models predit fewer but larger individual rain events. Identifying cover crop species and cover crop combinations that perform well under variable moisture will help producers select the most robus and cost-effective mixes. This study is evaluating the performance of functionally diverse cover crop mixtures under ambient and irrigated conditions. Preliminary data on the interactions between functionally diverse cover crops and weeds in two contrasting management systems, a conventional no-till system and an organic tillage system, in the Northern Great Plains under altered moisture regimes will be presented.

Cover Crop Safety Following Wheat Herbicide Application. Mike H. Ostlie*[1], Kirk A. Howatt[2], Caleb Dalley[3]; [1]North Dakota State University, Carrington, ND, [2]North Dakota State University, Fargo, ND, [3]North Dakota State University, Hettinger, ND (036)

Cover crops are becoming more important to wheat producers in the Upper Great Plains with increased awareness of soil health and more programs incentivizing the incorporation of cover crops into existing practices.Little research data exists about the effect of residual wheat herbicides on cover crops seeded the same season as application. A study was initiated in 2016 at three locations in North Dakota (Carrington, Fargo, Hettinger) to assess cover crop establishment success following herbicide applications to wheat. Nine herbicides were used in wheat (plus a check), and following wheat harvest, nine cover crop species were planted into each herbicide treatment. Cover crops were evaluated for stand and health. For simplicity, cover crop response was grouped into three categories; low risk (0-20% injury), medium risk (21-50% injury) and high risk (>50% injury). These categories were developed under the assumption that cover crop establishment of 80% would be a success but <50% is failure. Carrington had the highest injury level between the locations, even though it had the most rainfall after herbicide application. Fargo had the least injury, with no treatment resulting in greater than 20% injury. As a conservative approach, a figure was created that represents the greatest level of injury seen across locations. Since each location and year can cause different treatment responses, this was one way to generate data that producers can use for cover crop and herbicide planning while more data can be compiled over years.

Crop Response to Soil-Applied Herbicide Carryover. Daniel M. Adamson*, Gustavo Sbatella, Andrew R. Kniss; University of Wyoming, Laramie, WY (037)

Soil-applied herbicides are important for controlling weeds in many crops, as they offer a broadened control spectrum and chemical diversity, particularly when POST-applied herbicide options are limited. However, if soil-applied herbicides persist for an extended time, there is risk for damage to susceptible rotational crops in succeeding years. As herbicide degradation in the soil is dependent on water, among other factors, imminent needs to reduce agricultural water use could lead to limited herbicide degradation and a greater risk for carryover in the next growing season. This project explored how limited irrigation affects the carryover of soil-applied herbicides in irrigated crop rotations. A two-part field study was undertaken by applying 8 soil-applied herbicides to dry beans and corn. During the first year, 3 irrigation treatments (100, 85, and 70% of crop evapotranspiration) were applied with an overhead sprinkler. The following year, a field bioassay was conducted by planting sugar beet, sunflower, and corn or dry bean over the original plots. Crop response to residual herbicide was assessed as visible injury, stand, shoot biomass, NDVI, and yield. Reduced irrigation did not increase the risk of carryover. Instead, carryover was primarily determined by the inherent persistence of individual herbicides. Imazethapyr (0.11 kg ai/ha) consistently injured all rotational crops. Isoxaflutole (0.09 kg ai/ha) injured rotational dry bean and sunflower. Pyroxasulfone (0.18 kg ai/ha) injured rotational sugar beet. Atrazine (2 kg ai/ha), saflufenacil (0.07 kg ai/ha), ethalfuralin (0.84 kg ai/ha), trifluralin (0.56 kg ai/ha), and pendimethalin (1.06 kg ai/ha) did not injure rotational crops.

Mixtures of Glufosinate with 2,4-D or Dicamba for Cotton Weed Management. William B. McCloskey*; University of Arizona, Tucson, AZ (038)

Long-term use of glyphosate in Roundup Ready Flex cotton in Arizona selected for glyphosate tolerant weed species and glyphosate resistant Palmer amaranth. In response to herbicide resistant weeds, seed companies developed Dicamba, glufosinate and glyphosate (DGT) resistant cotton varieties to provide an additional weed management tool, dicamba, to cotton growers. Experiments were conducted at the University of Arizona Maricopa Agricultural Center to evaluate the control of annual morningglory and Palmer amaranth in DGT cotton and in weed studies using dicamba, glyphosate, glufosinate and tank mixtures of these herbicides. In the cotton studies, pendimethalin at 0.95 lb ai/A was applied PPI and prometryn (1.6 lb ai/A) was applied at layby. Sequential applications at 2 leaf cotton and 9 node cotton growth stage of dicamba (Engenia) at 0.5 lb ae/A and glyphosate (Roundup PowerMax) at 1 lb ae/A tank-mixtures resulted in complete control of annual morningglory and glyphosate susceptible Palmer amaranth. A sequential application of glyphosate at 1.5 lb ae/A followed by the dicamba+glyphosate (0.5+1.0 lb ae/A) tank-mixture similarly resulted in excellent control of annual morningglory and glyphosate susceptible Palmer amaranth. A tank-mix application of glufosinate (Liberty) at 0.79 lb ai/A + dicamba at 0.5 lb ae/A at 2 leaf cotton followed by a tank-mixture of Liberty at 0.53 lb ai/A + dicamba at 0.5 lb ae/A at 9 node cotton also provided good control of the two weed species. Other sequential application tactics did not provide as much control of the two species by layby. Late season rating of the amount of cotton canopy infested with morningglory found the most infestation in the preemergence Prowl only treatment (96% infestation) followed by the sequential Liberty alone treatment (0.79 followed by 0.53 lb ai/A) (36% infestation). Seed cotton yield was reduced in these two treatments but in all other treatments seed cotton yields were both greater and not significantly different from each other. In the weed studies, dicamba at 0.5 lb ae sprayed alone did not kill all of the larger Palmer amaranth and annual morningglory plants whereas tank-mixtures with either glufosinate or glyphosate did result in nearly complete control. As expected, the dicamba alone plots also had greater grass weed populations. In summary, dicamba will be a useful weed control tool for Arizona cotton growers, particularly those spraying glyphosate resistant Palmer amaranth populations.

Chemical and Physiological Interactions Between the Herbicides Glyphosate and 2,4-D. Marcelo R. de Figueiredo*[1], Agustin Zsögön[2], Valdemar L. Tornisielo[3], Lazaro E. Peres[3], Wilson da Silva[4], Dauri A. Fadin[5], Renata A. Sermarini[3], Todd Gaines[1], Pedro Christoffoleti[3]; [1]Colorado State University, Fort Collins, CO, [2]Universidade Federal de Viçosa, Viçosa, Brazil, [3]University of Sao Paulo, Piracicaba, Brazil, [4]EMBRAPA, Sao Carlos, Brazil, [5]Dow AgroSciences, Mogi-Mirim, Brazil (039)

Abstract not available

2,4-D and Dicamba Simulated Spray Tank-Contamination on Glyphosate- and Dicamba-Resistant Soybean. Marcelo L. Moretti*[1], Bryan G. Young[2], Julie M. Young[2]; [1]Oregon State University, Corvallis, OR, [2]Purdue University, West Lafayette, IN (040)

Soybean varieties resistant to the synthetic auxin herbicides dicamba or 2,4-D are available in the market or have anticipated release in near future. Over 15 million acres are forecasted to be cultivated with dicamba-resistant soybean varieties in 2017, and in-season use of dicamba will increase in tandem with planted acres. This new pattern of synthetic auxin herbicide use could result in greater off-target herbicide exposure by spray drift or spray tank contamination. Plants could now be exposed to tank contamination containing both dicamba and 2,4-D. It is unknown how dicamba-resistant soybean would respond to dicamba applications with 2,4-D as a tank contaminant. The objectives of this research were to: 1) evaluate whether the addition of dicamba at a field use rate would affect dicamba-resistant soybean response to 2,4-D, and 2) characterize glyphosate-resistant soybean response to 2,4-D or dicamba. Field experiments were conducted in eight states of the Midwest region during 2016. Glyphosate-resistant or dicamba-resistant soybean varieties were treated at two developmental stages: initial vegetative (V2) or reproductive (R1) stage. Yield loss was estimated using a non-linear regression using a Weibull model. In the glyphosate-resistant variety, response to herbicide was not dependent on soybean developmental stage at the time of treatment. The dicamba rate causing 50% yield loss (ED_{50}) was 73 ± 17 g ae ha^{-1} as compared to 564 ± 104 g ae ha^{-1} of 2,4-D. In the dicamba-resistant variety, soybean yield was significantly affected by 2,4-D applied as a tank contaminant with a ED_{50} of 545 ± 59 g ae ha^{-1}. Soybean response to 2,4-D was not affected by plant development stage or the addition of dicamba at field rate (560 g ae ha^{-1}). Based on these data, glyphosate-resistant and dicamba-resistant soybean have similar tolerances to 2,4-D. The response of dicamba-tolerant soybean to 2,4-D is not influenced by the addition of dicamba.

Management of Multiple Resistant Italian Ryegrass - Characterizing Resistant Populations. Lucas K. Bobadilla*, Andrew G. Hulting, Carol Mallory-Smith; Oregon State University, Corvallis, OR (041)

There are an increasing number of herbicide resistant *Italian ryegrass* populations in the Pacific Northwest of the USA, especially, in the Willamette Valley of Oregon. The objective of this study was to describe the resistance patterns in five populations of Italian ryegrass (FG-01, HR-01, JE-01, RD-01 and PR-01). Plants were collected from different fields where farmers reporter a poor control. These plants were grown in the greenhouse in isolation and seed collected. Greenhouse dose response studies were conducted to determine the resistance patterns. Seedlings were sprayed 17 days after emergence. A commercial cultivar was used as the susceptible population. Three herbicides were sprayed: glyphosate (0.58 to 37.41 kg ae ha^{-1}), clethodim (0.14 to 8.96 kg ae ha^{-1}) and pinoxaden (0.14 to 9.19 kg ae ha^{-1}). Twenty-one days after the application, mortality rate was documented and plants were harvested and dried at 52 °C for 3 days. Dry biomass was quantified.

Populations PR-01 and FG-01 were resistant to glyphosate and survived rates 29.5 and 6.1 times larger than the recommended field rate, respectively. Populations FG-01 and RD-01 were resistant to clethodim and survived rates 11.6 and 5.6 times greater than the recommended field rate, respectively. The RD-01 and FG-01 populations were resistant to pinoxaden and survived rates 9.68 times larger than the recommended field rate. Multiple-resistance in these populations from the Willamette Valley was confirmed. Future studies are needed to understand the mechanisms of resistance and how they might impact the spread of the resistance genes.

Russian Thistle (*Salsola tragus* L.) and Lambsquarter (*Chenopodium album* L.) Control in Sweet Corn. Tara Burke*, Rachel J. Zuger, Tim Waters, Ian C. Burke; Washington State University, Pullman, WA (042)

Chemical control options of economically significant weeds can be a valuable way to prevent yield loss. Growers often employ chemical methods for the control of two such weeds, Russian-thistle and common lambsquarters. Investigation was conducted of a new herbicide active ingredient, bicyclopyrone, for the control of broadleaf weeds in irrigated sweet corn grown in the Columbia River Basin of Washington. In sweet corn, bicyclopyrone represents a new active ingredient of the hydroxyphenylpyruvate dioxygenase (HPPD) inhibitor class of herbicides, and as such, could aide in the prevention of herbicide resistance through its addition to current herbicide rotation options. Therefore, the objective is to evaluate weed control and crop response to bicyclopyrone in comparison to currently used herbicides. All treatments were applied preemergence in the spring of 2015 and 2016. Primary and total ear number was significantly greater for all herbicides compared to the nontreated control. Percent weed control was greater for all herbicides when compared to the nontreated control. Mid-summer Russian-thistle control was greater for both the dimethenamid-P plus atrazine treatment as well as the pyroxasulfone plus fluthiacet and atrazine treatment, compared to the pyroxasulfone plus carfentrazone and saflufenacil treatment. All herbicide treatments were similar for mid-summer common lambsquarter control in 2016 (≥96%), mid-summer and late-summer nightshade control in 2015 (≥98%), and late-summer Russian-thistle control both years (≥78%). As supported by both crop response and weed control, bicycopyrone functions comparably to currently used herbicide options for Russian-thistle and common lambsquarters control in sweet corn.

Project 4. Teaching and Technology Transfer

DuPont™ PrecisionPac™ Customized Herbicide Dispensing System. Jeffrey T. Krumm*[1], Amanda L. Koppel[2], William L. Hatler[3], Keith D. Johnson[4], Ken Carlson[5], Helen A. Flanigan[6]; [1]DuPont Crop Protection, Hastings, NE, [2]DuPont Crop Protection, Richland, WA, [3]DuPont Crop Protection, Boise, ID, [4]DuPont Crop Protection, Grand Forks, ND, [5]DuPont Crop Protection, Johnston, IA, [6]DuPont Crop Protection, Greenwood, IN (043)

DuPont™ PrecisionPac™ Custom Blending Services System made possible by an innovative dispensing system, allow selected retailers to offer precise herbicide blends that match a grower's unique weed challenges, field size or spray tank volume. PrecisionPac™ custom blending delivery system saves time, money, and hassle by providing precise weed control with tailored herbicide blends more efficiently. Growers can now purchase a tailored blend for specific field sizes instead of a typical 40-acre increment leaving no leftover herbicide and packaging to be disposed of. The system dispenses dry herbicides into a custom-packaged container complete with a label specifying acres to be treated, contents, product label, and directions for use (DFU) for each registered component in the package. PrecisionPac™ is currently providing over 55% of bulk sales in Canada.

Project 5. Basic Biology and Ecology

Wild Oat Seed Viability After Panicle Emergence. K. Neil Harker[1], Breanne D. Tidemann*[1], John T. ODonovan[1], Chris J. Willenborg[2], Steve J. Shirtliffe[2], Eric N. Johnson[2], Elizabeth Sroka[1], Jennifer Zuidhof[1]; [1]AAFC, Lacombe, AB, [2]University of Saskatchewan, Saskatoon, SK (044)

Wild oat (*Avena fatua*) continues to be problematic in western Canada with a high percentage of seed shatter at harvest timing, dormancy, large populations, and high frequencies of herbicide resistant populations. However, wild oat typically exhibits a height differential with crops, particularly shorter crops such as lentil. The first year of a two year study was conducted in Lacombe, AB and Saskatoon, SK in lentil and wheat in 2015 to determine when wild oat seeds become viable, based on weekly panicle clipping and removal. Panicle clipping for each crop began when the majority of panicles were visible above respective crop canopies. Preliminary results indicate that wild oat viability increases with time. However, while wild oat viability at the first of the panicle clipping timings in lentil was near zero, by the first panicle clipping in wheat viability was between 12 and 37%. Weed management techniques that aim to target the panicle must occur quickly after wild oat panicle emergence above the crop canopy; later techniques will result in inputting of viable seed into the seedbank.

Kin Recognition in *Beta vulgaris*. Albert T. Adjesiwor*, Andrew R. Kniss; University of Wyoming, Laramie, WY (045)

Previous studies on shade avoidance (response to low red (R) to far-red (FR) light ratio) often recommended early weed removal as a management strategy for reducing the effects of shade avoidance on crop yield. However, since crops such as *Beta vulgaris* L. are often grown at high densities in the field, if crops are unable to distinguish reflected light quality of conspecifics from that of heterospecifics, early weed removal may not be an effective means for reducing yield loss due to shade avoidance. We evaluated the response of B. vulgaris to reflected FR light from *B. vulgaris*, *Chenopodium album* L., *Poa pratensis* L., *Medicago sativa* L., and bare soil (control). The study methods ensured there was no competition for water, nutrients, and light. At harvest (63 days after planting), number of leaves, leaf area, and root diameter per plant were significantly influenced by treatments. However, root fresh weight, root length, and root to shoot dry weight ratio were not influenced by treatments. There were 21 leaves in the control treatment compared to the 19, 18, 19, and 18 in *M. sativa*, *B. vulgaris*, *C. album* and *P. pratensis* treatments, respectively. The soil control had a leaf area of 1139 cm^2 which was 23 to 37% higher than all other treatments. Similarly, root diameter in control treatment was 46 mm which was 21 to 35% higher than all other treatments. *B. vulgaris* may not be able to distinguish reflected FR light of neighboring B. vulgaris from other plants species such as weeds.

Experimental Methods for Confirming Resistance to Dicamba. Carl W. Coburn*[1], Andrew R. Kniss[2]; [1]University of Wyoming, Laramie, WY, [2]University of Wyominig, Laramie, WY (046)

Full dose-response experiments may not be practical for testing a large number of samples due to time, space, and monetary constraints. Survival analysis is used in the engineering and medical literature to compare outcomes from different treatments or groups, and this analysis may have utility for herbicide resistance characterization. The purpose of this experiment was to determine the utility of survival analysis for examining differences in herbicide sensitivity between dicamba-susceptible and -resistant kochia (*Kochia scoparia*) in the greenhouse. For the dose-response experiment, the susceptible and resistant biotypes were treated with dicamba at rates ranging from 0 to 1400 g ae ha^{-1} or 0 to 2800 g ae ha^{-1}, respectively, with 5 replicates per dose. For the survival analysis experiment, both biotypes were treated with dicamba at 350 g ae ha^{-1} with 25 replicates per biotype. For the dose-response experiment, regrowth was assessed at weekly intervals up to 63 DAT, mortality was assessed at 21, 28, and 63 DAT, and dry weight was assessed 63 DAT. For the survival analysis, regrowth was assessed weekly up to 63 DAT. The dry weight selectivity index (SI), regrowth SI, and mortality SI at 63 DAT were 3.4, 8.4, and 113 for the dose-response experiment. For the survival analysis, the susceptible to resistant biotype ratio of the restricted mean regrowth time was 2.6, meaning it took the susceptible biotype 2.6 times longer to initiate new growth following treatment with dicamba. These results indicate survival analysis may be useful for resistance characterization.

Survival, Growth, and Fecundity of Kochia Cohorts with Varying Densities Under Different Crop Canopies. Charlemagne A. Lim*, Prashant Jha, Shane Leland, Anjani J; Montana State University, Huntley, MT (047)

Fields experiments were conducted in 2016 at the MSU–SARC, Huntley, MT to study the effect of crop canopy on survival, growth, and fecundity of kochia with varying densities. Treatments were arranged in a split-plot design with four replications. The main plot factor included crop canopy (soybean, sugar beet, corn, barley, fallow), and sub-plot factor comprised of kochia density (1, 5, 9, 18, 36, and 72 plants 0.371 m^{-2}). Kochia seeds from a population collected in Huntley, MT were used, and planted in the field on the same date as the crop. In fallow, kochia seeds were planted on April 5, 2016. Barley was planted on April 8, 2016, followed by sugar beet, corn, and soybean on May 4, May 5, and May 6, respectively. Crop and kochia seedling emergence were recorded. Kochia plant height, width, and number of branches were recorded at bi-weekly intervals. Biomass and seed production were recorded at harvest. Kochia biomass in sugar beet, soybean, barley, and corn were 51, 55, 78 and 84% less, respectively, compared to the biomass in fallow. Up to 92% biomass reduction was observed as kochia density increased from 1 to 72 plants 0.371 m^{-2}. Crop canopy reduced kochia biomass at lower kochia densities of 1 to 9 plants per 0.371 m^{-2}, but the effect was not significant at higher kochia densities of 18 to 72 plants m^{-2}. Kochia in fallow produced the most seeds (58,254 seeds $plant^{-1}$) followed by kochia in sugar beet and soybean (21,480 and 17,753 seeds, respectively), while kochia in barley and corn produced the least number of seeds (7,079 and 5,167 seeds $plant^{-1}$, respectively). Seeds produced at a kochia density of 1 plant 0.371 m^{-2} (60,482 seeds) were reduced by 57 to 93% as kochia density increased from 5 to 72 plants per 0.371 m^2. Crop canopy reduced seed production by 70 to 93% compared to seed production in fallow at lower densities up to 9 plants 0.371 m^{-2}; however, the canopy effect was not significant at a kochia density of 18 plants/0.371 m^2 or higher. Crop canopy effectively reduced kochia growth and fecundity, with corn as the most competitive followed by barley and soybean. Sugar beet was the least competitive crop. Growers should utilize these competitive crops such as corn and barley as an integrated strategy to manage kochia seed bank.

Growth and Development of Jointed Goatgrass (*Aegilops cylindrica*), Downy Brome (*Bromus tectorum*), and Winter Wheat (*Triticum aestivum*) in Response to Inter- and Intra- Specific Competition Under Greenhouse Conditions. Osama S. Saleh*, Andrew R. Kniss; University of Wyoming, Laramie, WY (048)

A greenhouse experiment was conducted to study winter wheat (*Triticum aestivum* cv,'AP503CL2'), downy brome (*Bromus tectorum*), and jointed goatgrass (*Aegilops cylendrica*) growth and development under inter and intra-specific competition. Winter wheat (cv, 'AP503CL2' WW), downy brome (DB), and jointed goatgrass (JGG) were grown in pots. The treatments used were species check (control) treatments, containing of one plant/pot of each species i.e., wheat (T1), downy brome (T2), and jointed goatgrass (T3). Intraspecific treatments, were composed of a single plant in the center of the pot and surrounded by 4 plants of the same species i.e., 1WW+4WW (T4), 1DB+4DB (T5), and 1JGG+4JGG (T6). Intraspecific treatments, contained one plant surrounded by 4 plants from another species i.e., 1WW+2DB (T7), 1WW+4JGG (T8), 1DB+4WW (T9), and 1JGG+4WW (T10). The experimental design was completely randomized design with 5 replicates. Plants were grown in the greenhouse for 3 months then leaf and tiller counts, leaf area, aboveground and belowground biomass were measured. Results were analyzed with ANOVA and means were compared via Fisher's LSD. Compared to control, winter wheat reduced tiller numbers in T4 68%, T9 69%, and T10 70%. The average leaf area reduced also in T4, T9, and T10 by 71%, 40%, and 49% respectively. When winter wheat was planted in competition to winter wheat, downy brome and jointed goatgrass in T4, T9, and T10, root biomass significantly increased. the root: shoot for T4 and T9 were double that of T1 and T2 respectively, and T10 biomass was 0.85g compared to 0.52 for T3.

Effect of Crop Rotation Diversity on Long-Term Kochia (Kochia scoparia) Management. Elizabeth G. Mosqueda*[1], Andrew R. Kniss[1], Gustavo Sbatella[1], Prashant Jha[2], Nevin C. Lawrence[3], David A. Claypool[1]; [1]University of Wyoming, Laramie, WY, [2]Montana State Universityn, Huntley, MT, [3]University of Nebraska-Lincoln, Scottsbluff, NE (049)

Combinations of cultural, mechanical, and chemical practices are often recommended in agronomic settings in order to combat the buildup of various pests, including weeds. Kochia (*Kochia scoparia*) has become one of western United States most problematic weeds, in part, because of evolved resistance to many common herbicides. Therefore, it is critical for research on non-chemical forms of weed control be continuously investigated to improve kochia control. A field study was initiated in 2014 near Lingle, Wyoming to examine interactions between crop rotation diversity, tillage, and herbicide application on kochia density. Four crop rotations consisted of continuous corn, corn-sugarbeet, corn-bean-corn-sugarbeet, and corn-bean-wheat-sugarbeet. Herbicide treatments included complete reliance on ALS inhibitors, mixtures including ALS inhibitors, or non-ALS herbicides. Tillage treatments included annual intensive tillage or minimum tillage. Kochia was counted in August of 2016, after three years of treatments being applied. Data was analyzed using a generalized linear mixed effects model, and treatment means were separated using Tukey's HSD when appropriate. Crop rotation and herbicide treatment had a significant effect on kochia density (P=0.002 and <0.001, respectively). Diverse crop rotations (corn-bean-corn-sugarbeet and corn-bean-wheat-sugarbeet) were associated with the lowest kochia density, with an average of 1.6 and >1 plant/m^2 respectively, compared to rotations with low diversity. Tillage practices had no impact on kochia density.

Unraveling Downy Brome (*Bromus tectorum* L.) Seed Dormancy in Agronomic Environments from the Inland Pacific Northwest (PNW). Amber L. Hauvermale*, Hannah C. Lindell, Ian C. Burke; Washington State University, Pullman, WA (050)

Downy brome is a highly successful invasive weed species in both natural and agricultural environments. Variation in seed dormancy and emergence are key factors contributing to the success of the species in the small grain production settings in the inland Pacific Norwest (PNW). Prior research identified four distinct seed dormancy scenarios among lines collected across the dryland cropping areas of the PNW, and demonstrated that phenotypic dormancy differences in downy brome are regulated by changes in sensitivity to the two plant hormones abscisic acid (ABA; dormancy promoting) and gibberellin (GA; germination stimulating). Genotypic studies in wheat, barely, and the model grass *Brachypodium distachyon*, establish that changes in seed dormancy are associated with changes in ABA biosynthesis and catabolism, and suggest by extension that expression of specific ABA and GA signaling genes may account for the variation in downy brome seed dormancy. Quantitative two-step RT-qPCR with primers to *Brachypodium distachyon* ABA signaling genes was used to measure expression of downy brome gene orthologues, *BtNCED1, BtNCED2, BtABA'OH-1,* and *BtABA'OH-2* in dormant and fully after-ripened embryos across four dormancy scenarios. Findings indicate that: 1) ABA biosynthesis (*BtNCEDs*) and catabolism (*BtABA8'OHs*) genes are present in downy brome 2) the expression of

BtNCEDs, and *BtABA8'OHs* are associated with dormancy and dormancy loss, and 3) expression profiles differ across dormancy scenarios.

GENERAL SESSION

Meeting Announcements. Monte D. Anderson*[1], Amy P. Ferriter[2]; [1]Bayer CropScience, Spangle, WA, [2]Crop Production Services, Boise, ID (051)

The 2017 printed program consisted of 125 papers and 50 posters for a total of 175 in this unique joint meeting of WSWS and WAPMS. This includes five presentations at the General Session but does not include the four WSWS discussion topics. The graduate student contest started out with 21 papers and 19 posters and ended up with 19 oral papers and 17 posters actually in the contest. WAPMS contributed a total of 38 papers and 3 posters with a total of 4 graduate students competing in the contests. Two WAPMS program slots were designated for discussion time and a business meeting. WSWS was represented by 87 papers and 47 posters. Changes to the meeting included a total of four withdrawn posters and two withdrawn papers. The submission of abstracts has gone very well, with only seven remaining of the total. Four of those are coming from the General Session, thus likely we will have nearly all abstracts available for the Proceedings.

The theme of a joint meeting of the 70th WSWS and 36th WAPMS was weeds of all types, whether on land, in the water, or as a crop. The General Session had General Announcements (Monte Anderson and Amy Ferriter) and Presidential Addresses (Kirk Howatt and Scott Nissen) from the WSWS and WAPMS, respectively. Lee Van Wychen discussed national science policy issues, including issues impacting water and agriculture nominees. Guest speaker Nick Zentner from Ellensburg WA discussed Ice Age Floods impact on Northwest agriculture and guest speaker Alan Schreiber of Eltopia WA discussed the economics and pesticide issues associated with growing cannabis.

With a joint meeting and three symposia, this year's meeting utilized all available time slots, particularly Tuesday afternoon and all day Wednesday. Symposia included Kaci Buhl's rescheduled risk communication from last year, Robert Norris discussing photography, and a group of invited speakers covering climate change put together by Eric Lehnhoff.

The following discussion topics were gathered by Prashant Jha on four of the five sections. Some discussion time allotments were a bit short and required section chairs to include a small amount of time to vote new chair-elects.

- Basic Biology and Ecology: Moving Beyond Herbicide Resistance: What are the Basic Biology and Ecology Research Needs in the Western U.S.
- Weeds of Range and Natural Areas: Study and Applications of Weed Risk Models in Plant Community Restoration.
- Weeds of Agronomic Crops: Herbicide Drift and Nozzle Selection for Weed Control Research in Agronomic Crops.
- Teaching and Technology Transfer: Open Access Publishing for the Open-Minded

Topics for future symposia were requested.

Presidential Address. Kirk A. Howatt*[1], Scott Nissen[2]; [1]North Dakota State University, Fargo, ND, [2]Colorado State University, Fort Collins, CO (052)

Welcome to the 2017 Annual Meeting. We have a beautiful venue and surrounding landscape to encourage camaraderie and scientific discussion. And a very fitting location on lake Coeur d'Alene to bring our two societies together. WSWS covering the terrestrial and WAPMS protecting the water, we can meet on the beach to share ideas and collaborate on common ground. We have many diverse and interesting presentations ahead in the next days. I hope you are able to participate in the broader scope of these meetings. I know I am looking forward to learning about different weed issues at some of the aquatic presentations. While the inception of this joint meeting happened a few years ago, the current architects have done a masterful job of pulling together and arranging a very full schedule. Monte Anderson and Amy Ferriter, program chairs from WSWS and WAPMS, respectively, with help from Prashant Jha, Brian Jenks, and Scott Cook, and lots of guidance from Phil Banks have put countless hours into construction of this meeting. We have a distinguished visitor. Janis McFarland, WSSA President, is attending the meeting. You may also have noticed new faces at the registration desk. This year student service support is provided by Mariano Galla, Neeta Soni, and Caio Brunharo as recipients of the Elena Sanchez travel awards. Other service opportunities for students include liaisons to the board, who have arranged all the silent auction items. Proceeds support the travel awards so please bid up the items and supports our students well. We also have the new Business Manager at the desk. Contract was signed with Interactive Management Incorporated for this position. Tara Steinke is our account manager. She has been a quick study and is already proving to be a wonderful asset to our organization. She also is the account manager for two other regional societies, so there will be good continuity among regions and potential synergy in oversight of activities. For those who have not read my last newsletter article, Andrew Kniss (Pres. Elect), Gustavo Sbatella (Res. Sec. Elect), and Brian Schutte (Ed. and Reg. Sec. Elect) were winners of the election and will join the Board at the end of these meetings. The Herbicide Resistance Listening Sessions requested by the WSSA Herb Res Education Committee were coordinated by three very capable groups. These were well received and provided a format for open discussion that yielded a large volume of information leading into the next Herbicide Resistance Workshop in Washington, D.C. These also provided valuable information leading into the Global Herbicide Resistance Challenge to be held in mid-May in Denver, CO of this year. This event is coordinated by Sandra McDonald, please visit with her if you are interested in more information. Thank you for attending to my requests last year. Public service announcement for this year is to update your contact information online so that Monte can reach the people he needs to find. You may be wondering about the weed images throughout the slides. They are the weed species covered in WSWS symposia over the past several years. We are always open to new topic suggestions. Please submit proposals before the summer board meeting. Many wonder about general metrics of our meeting. The past seven meetings have had attendance between 230 and 270. This year we have 230 WSWS members and an additional 75 WAPMS participants for attendance of more than 300 for the first time in more than eight years. The WSWS continues to have very stable and strong finances. Part of the reason is strong support from these WSWS sustaining members. In addition to dues, many of them support events at these meetings to keep society expenses down. Thank you to them and thank you to all who give service to keep our society functioning well and moving forward. Have a good meeting.

Washington DC Report. Lee Van Wychen*; National and Regional Weed Science Societies, Alexandria, VA (053)

Pruitt Confirmed as EPA Administrator. On February 17, 2017, the United States Senate confirmed Scott Pruitt as the 14th Administrator of the U.S. Environmental Protection Agency. The 49 year old Pruitt was born and raised in Kentucky where he graduated from Georgetown College in 1990. After that, he moved to Oklahoma where he earned his law degree at the University of Tulsa specializing in constitutional law. More on Administrator Pruitt at: https://www.epa.gov/aboutepa/epas-administrator

Zinke Confirmed as Secretary of Interior. Ryan Zinke was confirmed as the 52nd Secretary of the Interior by the Senate on March 1st by a vote of 68-31 after having to wait over a month after the Senate Environment and Public Works committee approved his nomination. The 55 year old Zinke served 23 years as a U.S. Navy Seal officer, retiring in 2008. He has a B.S. in Geology from the University of Oregon, a Masters in Business Finance from National University, and a Masters in Global Leadership from the University of San Diego. In November, Zinke had won his second term as Montana's sole Representative in the U.S. House. He is known both as an avid sportsman and conservationist. During his confirmation hearings, Zinke said he would take a "multi-use approach" to federal land management on the more than 500 million acres of public land managed by the Department of Interior. He also vowed to clear the estimated $12 billion backlog in maintenance and repair at national parks. More on Secretary Zinke at: https://www.doi.gov/pressreleases/ryan-zinke-sworn-52nd-secretary-interior

Perdue Nomination Hearing for USDA Secretary Hopefully Soon. Sonny Perdue was nominated for Secretary of Agriculture on January 18. Perdue, 70, was born and raised on a diversified row crop and dairy operation in central Georgia and earned a doctorate in veterinary medicine from the University of Georgia in 1971. Purdue served as Georgia's governor from 2003 to 2011. His Senate confirmation hearing is expected within the next two weeks with a final Senate vote by mid April. More info on Sonny is at: https://en.wikipedia.org/wiki/Sonny_Perdue

Federal Government Funded on CR Through April 28. Congress passed a continuing resolution (CR) just before midnight on Dec. 9, funding the government at FY 2016 levels through April 28, 2017. The new 115th Congress of the United States will have to deal with the remainder of FY 2017 funding as well as start on FY 2018 federal funding where sequestration will kick back in for discretionary spending. There will be much debate over how those recessions will be distributed between defense and non-defense programs or if there will be another budget deal to "raise the caps". Most federal research dollars depend on non-defense discretionary funding.

FY 2018 Budget Outline Expected This Week. The Trump administration plans to release its fiscal 2018 budget outline by the second week of March. This will be the "first draft" of Trump's full budget proposal, which is expected later this spring. It will lay out where his administration plans to boost spending, and specify which programs he will put on the chopping block. The House and Senate will craft their own spending plans later this spring. There is no question that the upcoming appropriations process will be tedious and require lots of input by stakeholders to justify federal programs use of taxpayer dollars.

Weed Science Societies Comment on EPA's Draft Guidance on Herbicide Resistance Management: Last summer EPA issued a Pesticide Registration Notice (PRN) that proposes an approach to address herbicide-resistant weeds by providing guidance on labeling, education, training, and stewardship for herbicides undergoing registration review or registration. The National and Regional Weed Science Societies recognize the critical need to protect all available weed management tools and are on record supporting proactive measures by EPA to combat the further evolution and spread of herbicide-resistant weeds. EPA's proposal represents a significant change in how resistance is monitored, mitigated and communicated to weed management stakeholders. We consider this proposal a first iteration that will need adaptation and evolution as our experience with it grows and we hope the Agency has those same expectations. Comments are at: http://wssa.net/wp-content/uploads/Natl-Regl-Weed-Sci-Comments-on-EPA-PRN-2016-XX.pdf

WSSA Comments on Glyphosate Carcinogenicity: WSSA fully supports EPA's Cancer Assessment Review Committee's (CARC) report on glyphosate and appreciates the scientific rigor and thoroughness of the CARC's review of all available epidemiology and carcinogenicity studies. WSSA agrees with the CARC's assessment that the few studies that the International Agency for Research on Cancer (IARC) selectively chose for its glyphosate review suffered from small sample sizes of cancer cases related to glyphosate exposure and had risk/odds ratios with large data variance beyond acceptable limits. Furthermore, WSSA feels that the IARC review process for glyphosate was flawed and represents a case of gross scientific negligence. There is no question that IARC arrived at their conclusion due to their inclusion of the positive findings from a selection of studies with known limitations, a lack of reproducible positive findings, and the omission of the negative findings from credible and reliable research. Finally, WSSA commented on the ongoing importance of glyphosate as a weed management tool and submitted information we developed surrounding some common misconceptions about glyphosate and herbicide resistance management. Comments are at: http://wssa.net/wp-content/uploads/WSSA-comments-to-FIFRA-SAP-on-glyphosate.pdf

Questioning of U.S. Funding for IARC Continues: House Oversight and Government Reform Chairman Jason Chaffetz (R-UT) has resumed his attacks on U.S. funding for the International Agency for Research on Cancer (IARC). NIH provides about $1 million a year in funding for IARC. Chaffetz asked NIH for access to all emails and other communications with IARC and the National Archives and Records Administration. The request stems from IARC's directive that members of its working group on cancer classifications not release information, even if they were U.S. government scientists.

WSSA Comments on Triazine Draft Ecological Risk Assessment: A number of concerns have been raised by various stakeholders relative to EPA's draft ecological risk assessment for the triazines. These concerns include: errors in endpoint data and the water monitoring database; use of models that are not validated with field data; estimates of inflated hypothetical risks (e.g. atrazine applications resulting in 36% bird mortality); use of data or findings not conducted in accordance with EPA's scientific guidelines required under FIFRA; and ignoring the advice and findings of previous Science Advisory Panels on atrazine. The WSSA stresses the importance of addressing these concerns in order to maintain stakeholder confidence in the Agency's science-based regulatory framework. Based on the current ecological draft risk assessment, atrazine and simazine would be restricted to less than 0.25 lbs a.i./A and 0.5 lbs a.i./A, respectively. At these low rates, atrazine and simazine would not provide efficacious weed control and would be a significant loss for herbicide resistance management plans. Comments are at: http://wssa.net/wp-content/uploads/WSSA-Comments-on-Triazine-Ecological-Risk-Assessment.pdf

New Paraquat Risk Mitigation Measures Final, EPA Grants Research Exemption. As part of the registration review process for paraquat, EPA proposed additional mitigation measures, such as paraquat-specific applicator training material and prohibiting backpack applications, in order to minimize human health incidents from paraquat. WSSA had several concerns related to the costs and requirements of some of the proposed mitigation measures, but our greatest concern was that prohibiting paraquat applications from hand-held equipment would essentially eliminate the weed science community's ability to do small plot research with paraquat. WSSA's comments are at: http://wssa.net/wp-content/uploads/WSSA-comments-on-paraquat-mitigation_FINAL.pdf

On Dec. 15, 2016, EPA finalized its mitigation decisions and implementation plan which can be found at: https://www.regulations.gov/document?D=EPA-HQ-OPP-2011-0855-0112. EPA addressed many of our concerns with their final decision, including providing a research exemption to a couple of the mitigation measure requirements. Specifically: "*The Agency recognizes that paraquat is widely used in agricultural research as a standard burndown and desiccant treatment, to which other herbicides and desiccants are compared. Because of its use as a standard treatment, it has high benefits for use in small scale research trials. Based on these facts and the comments received regarding the importance of paraquat for research purposes, EPA will grant a research exemption from the closed system requirement and the 'certified applicator only' requirement.*"

Education and Awareness of Auxin BMPs Will Be Critical. After the fallout from last summer's off label applications of dicamba, it is very clear that the weed science community will need to work extra hard on educating growers and applicators about appropriate best management practices (BMPs) for auxin herbicides. The products Extendimax with VaporGrip, Engenia, and Enlist Duo have been approved for use in 34 states, which includes the WSWS states of ND, NE, KS, OK, TX, NM, CO, and parts of AZ. There is a lot of excellent work going on already in many states across the country, but we must continue to get those auxin herbicide BMPs out there anyway we can. The WSSA Public Awareness Committee will be issuing a couple press releases this spring highlighting the auxin herbicide BMP's that were developed for www.TakeActionOnWeeds.com

Weed Science Societies Comments on Tank Mix Prohibitions: The National and Regional Weed Science Societies remain very concerned about the proposed tank mix prohibitions on new registrations due to EPA uncertainty on synergism effects on non-target organisms. We have strongly urged EPA to reconsider this prohibition, as it is counterproductive for herbicide resistance management, will result in significant economic costs to growers, will increase the carbon-footprint associated with weed management, and could be ignored by many practitioners. Mike Barrett, WSSA-EPA Liaison organized educational seminars at EPA by Bryan Young in June who talked about herbicide mixtures and by Greg Kruger in October who talked about droplet size and drift reduction technologies. There was a full day symposium on these topics at the WSSA meeting in Tucson and a good discussion with many federal agency personnel. http://wssa.net/wp-content/uploads/Weed-Science-Societies-comments-on-dicamba.pdf

Problems with EPA Worker Protection Standards (WPS) final rule. NASDA and the Assoc. of American Pesticide Control Officials (AAPCO) asked EPA to delay compliance of WPS revisions until Jan. 2, 2018. State lead agencies don't have the tools and financial resources necessary to effectively implement the rule changes (i.e. updated materials to train farm workers and especially to"Train-the-trainers"). EPA denied request. Most WPS revisions kicked in on Jan. 2, 2017. New Application Exclusion Zone (AEZ) requirements don't kick in until Jan. 2, 2018 for pesticide handlers. AEZ is the 100 feet "halo" surrounding aerial, air blast, fumigant, smoke, mist and fog application equipment, as well as spray applications using very fine or fine droplet sizes (<294 microns). AEZ is 25 feet for medium droplet sizes or larger. See: https://www.epa.gov/pesticide-worker-safety/revisions-worker-protection-standard

Seven Regional Herbicide Resistance Listening Sessions: Excellent work being done by WSSA Herbicide Resistance Education Committee, in particular David Shaw, Jill Schroeder, Mike Barrett, to organize these.

1) Dec. 5, Starkville, MS. Darrin Dodds & Larry Steckel.

2) Jan. 18. Lancaster, PA. Bill Curran, Mark VanGessel, Annie Klodd

3) Jan. 24. Pasco, WA. Ian Burke & Don Morishita

4) Feb. 15. Tulare, CA. Brad Hansen & Brian Schutte

5) Feb. 17. Holyoke, CO. Phil Stahlman, Todd Gaines, Andrew Kniss & Sandra McDonald

6) Mar. 4. San Antonio, TX. Commodity Classic. (Midwest region). Christy Sprague & Jeff Gunsolus

7) Mar. 30. Waynesboro, GA. Ramon Leon & Stanley Culpepper.

EPA Finalizes Policy to Mitigate the Acute Risk to Bees from Pesticide Products

EPA released its final policy which describes methods for addressing acute risks to bees from pesticides. The National and Regional Weed Science Societies commented on EPA's initial proposal which focused on 76 pesticides, three of them herbicides (bensulide, diuron, sethoxydim), which had an acute LD50 of less than 11 micrograms per bee. Our primary concern was that the proposed rule removed consideration of the exposure component completely from the risk assessment process as well as a benefits assessment in determining the need for and appropriateness of risk mitigation steps. Our submitted comments are available at: http://wssa.net/wp-content/uploads/National-and-Regional-Weed-Science-Societies-comments_Docket-ID-EPA-HQ-OPP-2014-0818.pdf

EPA stated the final Policy to Mitigate the Acute Risk to Bees from Pesticide Products is more flexible and practical than the proposed policy. For example, a product that retains its toxicity to bees for a shorter time might be allowed to be applied under certain circumstances. Also, in some cases, pesticide application would be allowed when it is unlikely that pollinators will be foraging for crops that have extended bloom periods. Their final Tier 1 list contains 43 active ingredients, with the **only herbicide being sethoxydim**. EPA will begin implementing this policy in 2017 by sending letters to registrants describing steps that must be taken to incorporate the new labeling.

"100% Weed-Free" Pollinator Habitat Seed Spreading Palmer Amaranth in CRP Land

Weed scientists are finding Palmer amaranth across the Midwest. Counties in black indicate Palmer amaranth was first found in an agricultural field, whereas red indicates it was first detected on conservation program land. Yellow signifies the source of introduction was not identified. Credit: Graphic by Julie McMahon, University of Illinois. Read more at: https://phys.org/news/2016-12-effort-seeds-destruction-midwest.html#jCp

National Plant Board Survey of Palmer Amaranth on State Noxious Weed Lists

Total number of States Responding	**States with Palmer amaranth Listed As A Noxious Weed**	**States considering adding to Noxious Weed List**	**States with Palmer amaranth Listed as a Prohibited Seed**	**States With Palmer Restricted Under their Seed Law**
33	3 – MN, OH, DE	6 – NV, MI, VA, PA, MD, ND	2 – MN, OH	1 – MS (as weed seed with $\leq$1% by weight tolerance)
66%	6%	12%	4%	2%

Monarchs and Milkweed: The total area occupied by monarch colonies at overwintering sites in Mexico in 2016-17 was estimated to be 2.91 hectares, which is less than the 4.01 hectares in 2015-16, but still a greater area than the previous 4 winters before that. By most accounts, the 2016-17 overwintering numbers are still better than anticipated given that the overwintering grounds were hit with a freak snowstorm in March 2016. States need to continue to map and track milkweed distributions as there is very little "real" data available. That aside, the monarch butterfly is now a national priority species of Working Lands for Wildlife (WLFW), a partnership between USDA NRCS and the U.S. Fish and Wildlife Service (FWS) that will focus on the eastern monarch population.

- NRCS will provide technical and financial assistance to help producers adopt conservation practices that benefit the monarch.
- FWS will provide producers with regulatory predictability should the monarch become listed under the Endangered Species Act (ESA).
- Predictability provides landowners with peace of mind – no matter the legal status of a species under ESA – that they can keep their working lands working with NRCS conservation systems in place.
- Initial focus is on 7 states in Midwest and 3 states in Mid South. (See below).

Water Infrastructure Improvements for the Nation (WIIN) Act Becomes Law. Just after midnight on December 10, 2016, the Senate passed the Water Infrastructure Improvements for the Nation (WIIN) Act on the last vote of the 114th Congress. The Senate vote was 78-21 and the House vote was 360-61. The legislation was subsequently signed into law on December 16, 2016.

The WIIN Act provides funding for water infrastructure improvements and research, reauthorizes the Great Lakes Restoration Initiative, **Lake Tahoe Restoration Act**, the Delaware River Basin Conservation Program, and **Columbia River Basin Restoration Initiative**; disburses critical resources to help communities provide safe drinking water, including grant financing to remove lead service lines; and provides funding to help communities expand water supply through investments in water recycling and desalination. The authorization of the **Aquatic Plant Control Research Program (APCRP)**, the nation's only federally authorized research program for the management of aquatic invasive species, remains at $40 million, with $20 million of that designated for watercraft inspection stations on the Columbia River in the Pacific Northwest. The full text of the WIIN Act is at: https://www.congress.gov/bill/114th-congress/senate-bill/612/text

WOTUS rule - Judicial, Legislative, and Executive Branch Actions. On November 1, 2016, opening briefs to the 6th Circuit Court were filed by 31 states, plus various organizations and companies opposed to the expanded federal jurisdiction over streams and wetlands under the Waters of the United States (WOTUS) rule finalized in 2015. The challengers argue that the WOTUS rule undermines state authority and take particular issue with what they say is the federal government's disregard for whether a body of water is considered "navigable," which they say should be key in determining where it can regulate. A 6th Circuit Court hearing is unlikely to occur before April 2017.

On Jan. 12, 2017, Senators Joni Ernst (R-IA) and Deb Fisher (R-NE) resurrected a resolution calling for the WOTUS rule to be scrapped. The nonbinding resolution would put the Senate on record as calling for the water rule to be withdrawn or vacated. The Senate fell just short of the 60 votes necessary to kill it last year, but with multiple moderate Democrats facing tough reelections in 2018, that could change. The new resolution could offer a test vote to see where lawmakers stand on the water rule now.

On Jan. 13, 2017, the Supreme Court agreed to hear a challenge by the National Association of Manufacturers (NAM) to a lower court ruling because of a provision in the Clean Water Act that lays out when challenges are allowed to leapfrog lower courts. NAM's petition argues that challenges to the water rule should be first heard by district courts, rather than by appellate courts, as the 6th Circuit Court decided, because they are closer to concerns on the ground.

On Feb. 28, 2017, President Trump ordered a revised WOTUS rule. His executive order directs the heads of the Army Corps of Engineers and EPA to "review and reconsider" the existing WOTUS rule, which likely means it will be resubmitted through the federal rule making process. The order instructs the two agency leaders to review a 2006 opinion written by late Supreme Court Justice Antonin Scalia in Rapanos v. United States. In that opinion, Scalia argued that federal jurisdiction extends only to water bodies with a permanent flow or non-navigable waterways that connect via surface water with areas with permanent flow — definitions with a more limited approach than the EPA established in its existing WOTUS rule that was finalized in 2015.

NPDES "Fix" Legislation Introduced in 115th Congress. New NPDES fix legislation has been re-introduced in both the House and Senate in the 115th Congress. The Reducing Regulatory Burdens Act of 2017 (HR 953) was introduced on Feb. 7, 2017 by Rep. Bob Gibbs (R-OH) and currently has 31 cosponsors. The House Agriculture Committee has already passed HR 953 by a voice vote on Feb. 16th. The companion bill in the Senate is S. 340 and was also introduced on Feb. 7 by Sen. Mike Crapo (R-ID) and Sen. Claire McCaskill (D-MO). S. 340 is titled the "Sensible Environmental Protection Act of 2017" and has 15 cosponsors. The NPDES-fix legislation has been passed by the House of Representatives in each of the last three sessions of Congress in 2011, 2013, and 2016.

National Invasive Species Awareness Week (NISAW). NISAW was held February 27 to March 3, 2017 in Washington DC. There were seminars and webinars every day of the week. All of the NISAW webinars were recorded and are available online at: www.nisaw.org. The first ever NISAW in the Field will be held this summer from July 9 – 15, 2017. Stay tuned for more information on state-led weed pulls, field days, seminars, and more. Finally, the Congressional Invasive Species Caucus has a new co-chair: Rep. Elise Stefanik (R-NY) who was first elected to Congress in 2015 and is the youngest member in the House of Representatives at 32. She represents the northern 1/3 of New York. Mike Thompson (D-CA), first elected to Congress in 1998 from California's wine country just north of San Francisco, will remain as the other co-chair of the Congressional Invasive Species Caucus.

Invasive Species Issues Farm Bill Task Force Team. A group of invasive species management stakeholders, led by the Reduce Risks from Invasive Species Coalition (RRISC) is drafting invasive species management language for the 2018 Farm Bill. Stakeholders include: American Forest & Paper Association, American Hort, Center for Invasive Species Prevention, Davey Tree Expert Company, Kansas State, Lone Tree Cattle Company, Lost Coast Forest Products, National Assocation of Conservation Districts, National Association of State Departments of Agriculture, National Cattlemen's Beef Association, National Wooden Pallet & Container Association, Noble Foundation, Northeast-Midwest Institute, Pacific States Marine Fisheries Commission, Society for Range Management, Society of American Foresters, State of Colorado, Syngenta, TNC, University of Georgia, US Chamber of Commerce, Vermont Woodlands Association, and WSSA.

A few examples of some of the invasive species management language the coalition is working on include:

- Adding weed treatment area designations under Healthy Forest Restoration Act

- Promoting Areawide IPM language and funding through USDA NIFA
- Prevent NRCS program participants from planting “invasive plant species” on “reserve” lands
- Pilot projects for landscape-scale testing of grazing as a tool for rangeland invasive species control
- Adding “invasive species” to the Foundation of Food and Agricultural Research’s list of national priorities

WSWS Region- Most Common and Troublesome Weeds in Broadleaf Crops, Fruits and Vegetables. In 2016, the National and Regional Weed Science Societies conducted a survey of the most common and troublesome weeds in the following broadleaf crop categories: 1) alfalfa, 2) canola, 3) cotton, 4) fruits & nuts, 5) peanuts, 6) pulse crops, 7) soybean, 8) sugar beets, 9) vegetables-cole crops, 10) vegetables-cucurbits, 11) vegetables-fruiting, and 12) vegetables-other. Common weeds refer to those weeds you most frequently see, while troublesome weeds are those that are most difficult to control (but may not be widespread). There were approximately 200 responses from weed scientists across the U.S. and Canada. Nationwide- the three most common weeds in broadleaf crops were: 1) *Chenopodium album*, 2) *Setaria* spp. and 3) *Ipomoea* spp.; while the three most troublesome weeds were 1) *Amaranthus palmeri*, 2) *Chenopodium album*, and 3) *Conyza canadensis*.

WSWS Region – Top 10 Weeds in Broadleaf Crops

Rank	Most Troublesome	*Times Listed	Rank	Most Common	Times Listed
1	kochia	32	1	common lambsquarters	30
2	common lambsquarters	21	T2	redroot pigweed	25
3	Palmer amaranth	19	T2	kochia	25
4	nutsedge spp.	18	4	foxtail spp.	20
5	waterhemp	14	5	Palmer amaranth	17
T6	Canada thistle	13	6	waterhemp	16
T6	field bindweed	13	7	nutsedge spp.	12
T8	horseweed (marestail)	12	T8	horseweed (marestail)	11
T8	hairy nightshade	12	T8	hairy nightshade	11
10	redroot pigweed	11	10	wild oats	10

As you would expect, there were no grass weed species listed as "troublesome" in the top 10 weeds in broadleaf crops. Eight weed species appeared on both the "most troublesome" and "most common" lists. Canada thistle and field bindweed, two notoriously difficult weeds to control, were on the most troublesome list, but not on the most common list. Four of the top five most troublesome weeds above have documented resistance to multiple herbicide mechanisms of action in the United States. The 2016 data set is available at: http://wssa.net/wssa/weed/surveys/

2017 National Weed Survey Now Available

The National and Regional Weed Science Societies 2017 survey for the most common and troublesome weeds is now available at: https://www.surveymonkey.com/r/2017weeds. **The 2017 survey focuses on weeds in grass crops**, specifically: 1) corn 2) rice, 3) sorghum, 4) spring grains, 5) winter grains, 6) pastures, and 7) turf. Please take a few minutes to complete the survey now!

APHIS Seeks Comments on Proposed Rule that Revises Requirements for Importation and Interstate Movement of Plant Pests, Biocontrol Agents, and Soil.

APHIS proposes to revise regulations that govern the movement into and within the U.S. of plant pests, biological control agents, and soil, and is soliciting public comments until **April 19, 2017**. Specifically, this action will align plant pest regulations with current APHIS policies, remove obsolete requirements, streamline the permit process for low risk organisms, and update requirements for the import of foreign soil. As it relates to the regulation of biological control organisms, this proposed rule would: 1) Establish criteria regarding the movement and release of certain biological control agents in the continental United States, and; 2) Establish exemptions for certain biological control organisms similar to what is being proposed for widely prevalent, low-risk plant pests. To review the proposed rule or submit comments, go to: http://www.regulations.gov/#!docketDetail;D=APHIS-2008-0076.

APHIS Seeks Comments on Revision of its Biotechnology Regulations. APHIS is proposing to revise its regulations regarding the importation, interstate movement, and environmental release of certain genetically engineered organisms in order to update the regulations in response to advances in genetic engineering and our accumulated experience in implementing the current regulations, as well as reduce the burden on regulated entities. This is the first comprehensive revision of the regulations since they were established in 1987. To view the proposed rule and submit public comments by **June 19, 2017,** see Docket No. APHIS-2015-0057.

In concert with the proposed revised regulations now being developed, APHIS is developing a process that includes an evidenced-based, standardized approach to assessing risk prior to making the decision whether to require controls (e.g. movement permits). This upfront risk analysis process will include either (in most cases): A Weed Risk Assessment (WRA) to characterize weed risk, if any, of genetically engineered (GE) plants, OR: A Plant Pest Risk Assessment (PPRA) for invertebrates, microorganisms, and GE plants (where appropriate), to characterize plant pest risk, if any.

Ice Age Geology: A Common Thread for Pacific Northwest Agriculture. Nick Zentner*; Central Washington University, Ellensburg, WA (054)

The Ice Age Floods of the Pacific Northwest have created a landscape ripe for agricultural production. Massive lava flows millions of years before the Ice Age laid the groundwork. Then starting 2.5 million years ago, the Ice Age provided thick ice sheets from the north - and tremendous Ice Age Floods that poured over the Inland Northwest dozens of times. The floodwater did massive amounts of erosion and deposition of the fertile soils of the Northwest. Today's agriculture is set throughout the Northwest - in the middle of Ice Age Floods erosional tracts and at the bottom of depositional Ice Age Lakes.

Cannabis: The Weed of the West! Alan Schreiber*; Paladin Agricultural Research, Eltopia, WA (055)

Cannabis production is no different from other agricultural crops in that it can become infested with a variety insect, mites and disease. Cannabis production is different from all other agriculture because it is illegal to federally register a pesticide for control of insects and disease. The Washington State Department of Agriculture has developed a list of products that are considered not illegal to use on cannabis in Washington. Many of these products have no practical pest management value. Many other of these products have limited efficacy, short residual or other attributes that limit their usefulness to cannabis growers. Due to the expectation of superior quality and the extremely high value of their crop, cannabis growers are under heavy pressure to control insects, mites and diseases. Due to the combination of these factors growers are using a wide array of pest management products and practices, some of which may be illegal and may pose a risk to pesticide applicators, cannabis workers and cannabis consumers. This situation is exacerbated by a federal probation on Washington State University and USDA conducting pest management research, development of alternatives to pesticides, pesticide applicator training or training on worker protection from pesticides. The lack of appropriate mechanisms for pesticide applicator and worker protection standards training, the lack of adequate crop protection tools and the absence of traditional research and extension outreach programs has created a "Wild West" mentality where any kind of pest management tactics can occur. The void of traditional pest management research, extension and appropriate tools has created serious and potentially dangerous conditions in cannabis production. Following a pesticide label has historically not been among the most important considerations in the illegal production of cannabis. What is different is that cannabis is legally available for medical purposes for the large majority of the U.S population and is completely legal in several states. The widespread legalization of cannabis is bringing historical cannabis pest management practices into public view.

WESTERN AQUATIC PLANT MANAGEMENT SOCIETY: AQUATICS

Aquatic Plant Management Society (APMS) - an Update from the President. John Madsen*; USDA-ARS, Davis, CA (069)

No abstract for this timeslot.

Aquatic Plant Management Regulatory Update - What is on the Horizon? Carlton Layne*; AERF, Atlanta, GA (070)

No abstract for this timeslot.

Intentionally Applying Pesticides to Water? Tips on NPDES Permit Compliance. Michael S. Blankinship*; Blankinship & Associates, Inc., Davis, CA (071)

Is reading and following the product label enough? Intentional introduction of pesticides into Waters of the US to control algae and aquatic weeds adds another requirement: NPDES permit compliance. The permit requires that you know what herbicides to use and where (and where not) to apply them. Details, tools and examples will be presented to help you recognize if you need a permit and if you must have one, how to comply with it in a cost-effective manner.

Socioeconomic Impacts of Eurasian Watermilfoil in the Coeur d'Alene region. Felix Liao*; University of Idaho, Moscow, ID (072)

Amenity value of water resources has become a major driving force of recent population growth in the region centered on Coeur d'Alene Lake in northern Idaho, USA. Despite regulatory measures aimed to protect lake water quality, surface water quality is increasingly threatened by lakefront development and invasions of Eurasian watermilfoil (Myriophyllum spicatum), a non-indigenous aquatic species. We used hedonic modeling to estimate the effects of ambient water quality and the presence of Eurasian watermilfoil on lakefront property values of single-family homes in the Coeur d'Alene area. We find that property values are positively associated with Secchi depth (a proxy of water quality or clarity), and negatively related to the presence of milfoil. Results of spatial regime analysis indicate the geographical variations of these associations. The presence of milfoil was related to a 13% decline in mean property value, corresponding to $64,255, on average, lower property sales price. Our study demonstrates that proactive mitigation approaches to cope with potential environmental degradation in lake ecosystems could have significant economic benefits to owners of lakefront properties and local communities.

Coeur d'Alene Lake Milfoil Control Program Update. Ben Scofield*; CDA Tribe, Plummer, ID (073)

Coeur d’Alene Lake is a large lake (32,000 acres) located in northern Idaho. Coeur d’Alene Lake has been at the center of the Coeur d’Alene Tribe’s culture and existence since time immemorial. Additionally, the lake supports a wide variety of uses including fish and wildlife habitat, recreation, hydropower, as well as other uses. *Myriophyllum spicatum* was first identified in Coeur d’Alene Lake in 2004. Infestations are mainly located in the southern portion of the lake where there is extensive littoral habitat. In 2006, a hybrid of *M. spicatum* crossed with *M. sibiricum* was identified in the lake. Treatment of nuisance *Myriophyllum spp.* began in 2006 and has occurred annually since then. Control techniques have included herbicide (2,4-D or 2,4-D/endothall combination), suction dredge removal, bottom barrier placement, and hand pulling. Nuisance *Myriophyllum spp.* often grows in small patches (< 5 acres) or in long skinny strips which has presented challenges in maintaining adequate contact times. Other challenges have included variable herbicide treatment results thought to be due to differences in how hybrid *Myriophyllum* responds to herbicide treatment. Another challenge has been monitoring aquatic plant community dynamics as a whole. Numerous other factors are thought to influence *Myriophyllum spp.* presence in a given year such as growing season condition, severity of annual lake level drawdown, and herbivory. Given the observed variability of *Myriophyllum spp.* at non-treatment sites much more work is needed to help differentiate between treatment and environment condition effects. Long term and within season monitoring results will be discussed.

Progress and Challenges in Aquatic Plant Management: A State-Wide Perspective. Thomas Woolf*; Idaho Department of Agriculture, Hayden, ID (074)

The Idaho Department of Agriculture's Aquatic Plant Management Program has encountered significant challenges over the years. Today, through the diligent efforts of partners, stakeholders and staff, significant progress on some of the most challenging aquatic noxious weeds is now being achieved. Treatment programs on populations of hybrid milfoil, flowering rush and hydrilla are increasingly more effective and ongoing research promises to improve treatment efficacy into the future.

Idaho's Cooperative Weed Management programs and how County Weed Programs are key to reducing impacts of invasive weeds due to local control and working groups. Jeffrey Pettingill*; Bonneville County Weed Control, Idaho Falls, ID (087)

Idaho County Weed Superintendents and how their programs work in conjunction with being the center of the “hub’ for Cooperative Weed Management Areas and how the overall coordination and collaboration of local decision makers come together for effective invasive weed management for either on land or water. This is especially important when it comes to choosing the proper tool for an integrated weed management program, regardless of whom owns the land(s) or control issue on the water.

Montana's Noxious Weeds Program. Dave Burch*; Montana Department of Agriculture, Helana, MT (088)

This presentaation will review Montana's Noxious Weed program and where it is heading. With more emphasis being put on aquatics and "invasives - All-Taxa" how this is effecting noxious weed programs in the state. What change is needed and how will we co-exist?

Lake Tahoe's Aquatics Program - An Update. Dennis Zabaglo*; Tahoe Regional Planning Agency, Stateline, NV (089)

Abstract not available

The Invasive Species Council of British Columbia. Danielle Toperczer*; Invasive Species Council of BC, Vancouver, BC (090)

The threat of invasion of key aquatic invasive species is of primary concern throughout the Pacific Northwest. To prevent and combat these potential invasions, partners in BC have been working diligently to develop and refine their approaches and messaging to enable the public and industry to adopt and instill measures and actions to protect our waterbodies. The Clean Drain Dry program was launched in BC in 2012 as a targeted changing behaviour program designed to educate boaters on responsible actions to take to prevent the spread of aquatic invasives. Danielle will discuss the background and implementation of the Clean Drain Dry program, the Invasive Species Council of BC's partnership with the Province of BC and the Province's swift action to establish and maintain watercraft inspection points.

From Zero to Sixty: Tracing the Evolution of Alberta's Aquatic Invasive Species Program. Kate Wilson*; Government of Alberta, Edmonton, AB (091)

Alberta’s Aquatic Invasive Species Program has advanced from being nonexistent to a comprehensive and multi-faceted provincial program that has achieved broad-based public and stakeholder support in a short amount of time. The foundation of this program is based on incredible agency and stakeholder partnerships, collaborative opportunities, and capitalizing on the experience of others, while making efficient use of available resources.

While there are many aquatic invasive species (AIS) that pose a risk to Alberta waters, quagga and zebra mussels (*Dreissena rostriformis*, *Dreissena polymorpha*) are a significant concern due to the threats they pose to water conveyance infrastructure and the aquatic environment. Alberta is home to the most irrigation infrastructure in Canada, and this is a very tangible threat. An economic impact assessment conservatively estimates annual costs to Alberta in the event of an invasive mussel infestation to be more than $75 million. While the initial focus of the AIS Program was dreissenid mussels, it has since progressed to become multi-taxa in scope.

The AIS Program includes the following elements: watercraft inspections, monitoring, education & outreach, response, and legislation & policy. Mandatory watercraft inspection stations are conducted throughout the province, focusing on high risk areas (e.g. borders). The *Fisheries (Alberta) Act* was amended in 2015 to allow for a more robust approach to prevention and management – including a prohibited AIS list of 52 aquatic invasive plants, invertebrates and fish. Two educational campaigns focused on behaviour change and social marketing have been launched. Monitoring for invasive mussels has been initiated in over 70 lakes and reservoirs in the province annually. Response plans are currently being finalized. Just recently, Alberta was the first province to exercise the authorities provided in the new federal AIS Regulations under the *Fisheries Act* to eradicate an infestation of Black Bullhead and respond to a Phragmites introduction. Response efforts are ongoing to address existing challenges such as flowering rush and non-native carp introductions. Presentation will cover successes and challenges to address for future sustainability.

Mussels and Mutts: The Alberta Conservation K-9 Program. Cynthia Sawchuk*; Government of Alberta, Canmore, AB (092)

Ms. Sawchuck and Hilo will provide a live demo of K-9 mussel detection capabilities. This is an interactive session with WAPMS audience members

Live Demo – Alberta's K-9 Detection Program. Cynthia Swachuk* and Hilo, Government of Alberta, Canmore, AB (093)

Using Bathemetry and Plant Volume Analysis to Accurately Calculate Aquatic Applications and Record Results. David Kluttz*; Lakeland Restoration Services, LLC, Priest River, ID (113)

Electronic bathymetric technology has evolved since its invention in 1948. Commercial production of recreational units was in full swing by the year 2000. In the years since, capabilities of this technology has grown into a simple process to evaluate the parameters required to analyze project areas providing for safe, accurate aquatic treatments. This discussion will cover BioBase and ArcView technology as it relates to developing treatment plans and analyzing the effects of herbicide treatments. Pre and post treatment analysis as well as herbicide application methods, products rates, strategies and results will be discussed.

Efficacy of Aquathol and KFD-94-10 for Curlyleaf pondweed (*Potamogeton crispus*) control under simulated fall conditions. Jéssica Scarpin*[1], Mirella Ortiz[1], Scott Nissen[1], Cody Gray[2]; [1]Colorado State University, Fort Collins, CO, [2]UPI, Fort Collins, CO (114)

Invasions of non-native aquatic plants such as curlyleaf pondweed (*Potamogeton crispus*) (CLP) can have wide-ranging negative effects on whole lake ecosystems. Herbicide treatments have been shown to successfully control invasive aquatic plants during treatment years. Endothall and 2,4-D have been used in combination to control CLP for over 10 years. The objective of this research was to determine the efficacy of endothall (Aquathol® K) alone and endothall+2,4-D (Chinook®) for CLP control under simulated fall conditions. CLP plants were grown from turions in 50ml falcon tubes containing field soil, slow release fertilizer and fine, unwashed sand. When the plants reached 15cm, they were treated with either endothall or endothall+2,4-D. Five-gallon mesocosms filled with 4 gallon of tap water were treated with one of the five treatments (non-treated, endothall 1.5ppm and 0.75ppm, or endothall+2,4-D 1.5+0.6ppm and 0.75ppm+0.3ppm, respectively). Three plants were exposed for 3, 6 or 12 hours to each treatment, triple rinsed in clean water and transferred to five-gallon mesocosms containing non-treated water. The plants were kept in growth chamber, at 14C with 12-hour day length. Visual control ratings were taken at 7, 14, 21 and 28 days after treatment. All the endothall+2,4-D treatments provided 100% CLP control, while treatments with only endothall did not. In addition, plants treated with endothall+2,4-D had more rapid symptom development than those treated with endothall alone.

Screening herbicides for management of waterhyacinth in the California Bay Delta. Guy B. Kyser*[1], John Madsen[2], John Miskella[2], Christy Morgan[2]; [1]University of California, Davis, CA, [2]USDA-ARS, Davis, CA (115)

Waterhyacinth, native to central and South America, is one of the world's worst aquatic weeds. In the US it has naturalized in subtropical wetlands in the southeastern states, California, and Hawaii. In California's Sacramento-San Joaquin Delta, waterhyacinth forms extensive floating mats that comprise a threat to habitat, water supply, recreation, and commercial navigation. Non-chemical management strategies (mechanical harvest, hand removal, biocontrol) are only partially effective; chemical treatments (glyphosate, 2,4-D) can be effective but are too hampered by regulation to keep up with the spread of this weed. In order to address agency concerns and public perception over the potential impact of herbicides on the environment, we conducted a series of trials comparing different aquatic-registered adjuvants and herbicides. Trials were performed on waterhyacinth confined in floating 1-m^2 quadrats in four replications per treatment. In summer 2015 we applied glyphosate (1681 g ae ha^{-1}) in a spray volume of 935 L ha^{-1} with the surfactants *Agridex*, *Rainier-EA*, *Competitor*, or *Cygnet Plus*, each at 1.75 L ha^{-1}. *Agridex* provided significantly greater reduction in waterhyacinth height and biomass than the other surfactants. In summer 2016 we conducted two herbicide trials, with all treatments including *Agridex* (3.51 L ha^{-1}). In the first, we compared 2,4-D and glyphosate (standard treatments for waterhyacinth) with the newer herbicides imazamox and penoxsulam. The new chemicals provided equivalent or better control at lower use rates. In the second trial, we compared a broader rate range of imazamox and penoxsulam with glyphosate. Imazamox (280 to 560 g ae ha^{-1}) and penoxsulam (25 to 98 g ha^{-1}) produced better control of waterhyacinth than did glyphosate (1681 g ae ha^{-1}). Adoption of these new chemicals, and application with an effective surfactant, would allow effective control of waterhyacinth while greatly reducing the amount of active ingredient introduced to the environment.

Biological control of *Phragmites* in the United States. Mark Schwarzlaender*[1], Hariet Hinz[2], Patrick Haefliger[2]; [1]University of Idaho, Moscow, ID, [2]CABI Europe-Switzerland, Delemont, Switzerland (116)

Common reed, *Phragmites australis,* is considered invasive in North America and is agressively controlled in many states. Based on molecular analysis it became apparent that the genus *Phragmites* in North America consists of a single species but includes three different lineages, two of which are considered native, *Phragmites australis* ssp. *Americanus* and *P. australis* ssp. *berlandieri.* This complicates the search for a biological control solution for invasive *Phragmites*. Any biocontrol agent considered for release in North America would need to be subspecies specific. Currently, two noctuid moths, *Archanara geminipuncta* and *A. neurica,* are being studied for their potential for invasive reed control at CABI Switzerland and the University of Rhode Island. No-choice development tests demonstrated that larval development is restricted to the genus *Phragmites,* but that development is possible on both native subspecies. In several open-field tests it could be shown, however, that both moths highly prefer invasive *Phragmites* for oviposition. In addition, any eggs laid on *P. australis* ssp. *Americanus* would suffer higher overwintering mortality than eggs laid on invasive reed due to differences in phenology. Since *P. australis* ssp. *Berlandieri* only occurs on the Gulf Coast of the U.S., an experiment is underway to see whether larvae of the two moth species successfully hatch if eggs are kept under Gulf Coast climate conditions. Overall, we are convinced that the introduction of *A. geminipuncta* and *A. neurica* would only pose a negligible risk to the native *Phragmites* subspecies, while potentially having a major impact on the vigor of invasive *Phragmites.* A petition for field release is currently being prepared.

Biological control of water hyacinth in California's Delta: current status and a roadmap for the future. Paul Pratt*; USDA/ARS, Albany, CA (117)

The Sacramento-San Joaquin River Delta is a critical water resource in draught stricken northern California. Services provided by the Delta are severely limited as a result of the floating aquatic weed Eichhornia crassipes. Three biological control agents were released in 1983 and a fourth was released in 2013. Little is known concerning which of these insects established persistent populations or their resulting distributions across the complex and dynamic aquatic landscape. Monthly surveys of 16 locations across the Delta were initiated in June 2015. Sampling to date revealed that only a single biological control agent was uniformly established throughout the Delta: the weevil *Neochetina bruchi*. From all of the study sites, 96.6% of the examined weevils were identified as *N. bruchi*, and all of the 3.4% *N. eichhorniae* were recovered from two sites just south of the Delta. Weevil densities (larvae and adult weevils per destructively sampled plant) varied spatially and temporally. Peak mean densities of 6.31 weevils were found at one site and 0.31 weevils at another site just 12 km away, averaged across sampling from August-November. Mean densities across all sites were the lowest in June 2015 (0.54 weevils), increasing in August to 5.35 weevils, and peaking in November at 6.22 weevils, with a maximum density of 39 weevils per plant in August. The proportion of damaged leaf area from weevil feeding increased concomitantly with weevil densities. *M. scutellaris* remained established at its original release site but has not dispersed into the other surveyed regions. We propose hypotheses to explain patterns in species establishment and distribution. Additional biotypes of existing biological control agents may improve control of *E. crassipes*. Vetting new candidates for control of the floating weed are discussed.

Impacts of Flowering Rush on Western Aquatic Resources. Peter M. Rice*[1], Virgil Dupuis[2]; [1]University of Montana, Missoula, MT, [2]Salish Kootenai College, Pablo, MT (118)

Introduced exotic macrophytes are "ecosystem engineers" as a consequence of their propensity to alter the structure and functions of aquatic environments and dependent biota, and human utilization of aquatic resources. However, other than a strong propensity to form monotypic or near monotypic stands, the higher order impacts of flowering rush have not received much scientific study. It is widely accepted that flowering rush has strong impacts on recreational, irrigation, and industrial use of shallow waters, and that its monotypic tendencies may be affecting native littoral species. Obvious impacts are resultant from the occlusion of open water and restrictions on flow. Irrigation delivery in the Flathead valley is being reduced by flowering rush. This flowering rush impact on irrigated agriculture is well recognized in southeast Idaho. The Aberdeen-Springfield canal system provides water for irrigation of potatoes and other cash crops. Approximately 150 miles of the 300 miles of the main delivery canals has been infested with flowering rush and required removal by mechanical methods every 2nd or 3rd year. Recreational uses of Flathead Lake , Lake Pend Oreille, and small lakes in mid-western states are being impaired by dense monotypic infestations adjacent to the shoreline and docks. This includes impediment of boat passage due to prop fouling, blockage for swimming, and loss of open water for near shore fishing. Flowering rush provides ideal habitat for great pond snails, which are an intermediate host for the trematode parasite that causes swimmer's itch. The most critical environmental aspect of flowering rush invasions is its ability to form dense stands in previously unvegetated littoral zones. As the extent of unchecked infestations increases there are likely to be trophic and ecosystem cascades. These would be the result of increased water temperature, nutrient transfers from the hydrosoil to the water column, altered sediment transport, deposition, and accretion rates; and formation of a dense but simplified three dimensional canopy structure. Swimmer's itch may be dismissed as a simple nuisance, however, it is indicative of other higher order biotic impacts that are reasonable hypotheses of long term consequences of this invasion. Aquatic food webs are likely to be changed. Our investigations of flowering rush since 1997 appear to indicate that flowering rush is inducing a classical "invasional meltdown" by facilitating other introduced and invasive species. Of particular relevance for Native Tribes throughout the Pacific Northwest are the negative impacts of flowering rush on the maintenance and restoration of native salmonids. The expanding stands of flowering rush provide habitat for structurally orientated introduced fish that are obligate vegetation spawners. Some introduced fish are ambush predators of cutthroat trout, bull trout, and juvenile salmon. These vegetation-adapted piscivorous species include small and large mouth bass, yellow perch, and northern pike. The negative impact of structurally orientated introduced fish on open water salmonids throughout the Columbia River Basin and other western states is well documented. Northern pike are having serious impacts on cutthroat and federally listed endangered bull trout. Sloughs on the Flathead R. that are being utilized by radio tagged adult northern pike are heavily infested with flowering rush. Vegetation and plant litter are the key factors in adult northern pike habitat selection in that vegetation is mandatory for spawning, rearing juveniles, and used for ambush predation. Northern pike are utilizing mats of senesced flowering rush leaves from the previous year as their spawning beds. Juvenile northern pike are strongly associated with vegetated habitat, where they can feed on small prey but also be sheltered from their predators which include cohorts of slightly larger cannibalistic juvenile northern pike. We believe that as new flowering rush leaves emerge in May, the larval pike are attaching to these new leaves; then the juvenile stage shelters from cannibalistic predation in the thickening new growth.

Research on the phenology of flowering rush in the western United States. John Madsen*[1], Kurt Getsinger[2]; [1]USDA-ARS, Davis, CA, [2]USAERDC, Vicksburg, MS (119)

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 are measured weekly, and biomass samples are collected monthly from each population. At this point, no growth differences between populations have been detected. Bud formation begins 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). Bud densities range from 500 to 1200 rhizome buds per square meter, which translates to between 2 and 5 million buds per acre. The goal of long-term management, at least for triploid flowering rush, showed be to prevent bud formation and deplete the rhizome bud bank.

Spread and Control of Flowering Rush in Washington and Oregon: Lakes and Rivers. Jenifer Parsons*; Washington Department of Ecology, Yakima, WA (120)

Flowering rush was first identified in Washington state in 1997 in a small lake. However, it did not cause concern until the alarm was raised about expanding flowering rush populations in Flathead Lake, Montana. Since that time, it has been discovered in 3 major tributaries of the Columbia River as well as the River itself in both Oregon and Washington. In these rivers, flowering rush spreads rapidly via currents when rhizome fragments and buds break loose from parent plants. Two separate locations are also known from western Washington lakes, and all populations tested are triploid and genetically identical.

Control methods deployed so far are largely dependent on local conditions. In one lake a multi-year herbicide trial has shown that where submersed growth is the dominant form, diquat will significantly reduce growth when treatments occur for multiple years. In areas where emergent growth can be sprayed, glyphosate is reducing growth. In sensitive areas, places with very small numbers of plants, areas with strong flow and areas where permitting doesn't allow for any alternatives, divers are employed to hand pull and cover plants with benthic matting. In spite of these efforts, flowering rush is not yielding ground easily, and in most areas continues to expand.

Spread, Survey and Management of Flowering Rush in the Pend Oreille, a Regulated River.
Sharon L. Sorby*; Pend Oreille County, Newport, WA (121)

The Pend Oreille River flows from Lake Pend Oreille in Idaho for 130 miles (209 km) to reach its confluence with the Columbia River just north of the Waneta border crossing into British Columbia, Canada. Although the Pend Oreille basin's drainage area in the US and BC accounts for less than 10% of the entire Columbia River watershed, the basin contributes 43% of the water volume to the Columbia River.

The Pend Oreille River has two dams in British Columbia, Seven Mile and Waneta; and, three dams in the US, Albeni Dam in Idaho, Box Canyon Dam and Boundary Dam in Pend Oreille County, Washington. All dams generate power and each has its own regulatory mandates to meet. Along with natural weather patterns, the result is widely fluctuating water levels and flows. Moderate to high flows are experienced late September into November as the Pend Oreille Lake level is dropped to its lower winter level. Low to moderate flows are experienced through the winter months and the spring brings high to flood stage flows with local and upstream snow melt run-off. Flows taper off in mid-July and low flows return by August into September. All of this fluctuation distills down to a very short window for survey and management efforts to discover and suppress flowering rush infestations.

We have made a number of observations, yielding hypothesis, and learned a few lessons. Based on a higher number and more densely populated infestations of flowering rush in deeper and faster moving water, we think infestations start in these areas. This has led us to think that it is pre-adapted to spreading in fast current water. The observation of the bullet shape and low buoyancy of the bulbil reproductive structure, has led us to think that it "flies" through the high current of the deeper water until it impacts an obstacle or a radical shift in current that sends it into a tumble allowing it to more easily lodge and take root. If conditions are right for one bulbil to take up residency, then with the massive number of bulbils being released upstream, more will fallout in the same area and populations can build rapidly. As the more buoyant rhizomes break free from these deeper water infestations, they can float into the slack-water areas where flotsam collects. By the time these more easily identifiable infestations are discovered, there is a larger "seed" source looming nearby.

The deep fast water infestation discoveries have led us to add benthic maps to our survey tool box, diving if necessary, to check areas 20-40 feet deep at normal pool levels, and add areas where debris, rocks or other obstacles occur to our survey coverage.

Management to date has included treating the shoreline populations with the herbicide glyphosate at the 2%-6% v/v rate by back-pack and power sprayer, yielding 75%-100% control. (Visually ascertained, not quantified). Upland (seasonally inundated) areas were treated with herbicide mixes of either proprietary aminopyralid + metsulfuron methyl at 0.0825 ounces per gallon by power sprayer or triclopyr + metsulfuron methyl at 1.78 ounces per gallon + 0.5 gram per gallon respectively by back-pack sprayer, both yielding 99.9%-100% control. (Visually ascertained, not quantified). At this time, current velocity and abundant potable water in-takes along the shoreline prevent in-water herbicide treatment.

The in-water infestations have been treated by diver assisted suction (DAS). Over the three years we have employed this method, many more lessons have been learned and adaptations made to both equipment and methodology. First, a smaller mesh screen (minus 0.25 inch diamond mesh) was installed in the containment basket. As the suction hose needs at least six inches of water to operate, the pump was modified to allow a hose hook-up and under pressure, placer the shallow infestations from the heavy clay substrate, rolling them up like sod. Large table-top sieves (dubbed clarifiers) were built to safely wash the clay from the roots to prevent sediment transport. Due to the linear nature of the majority of infestation sites, a two-point anchor system with a dragline between was employed to keep the boat nearer to the infestation area and the diver safer.

Adequate monitoring for these methods has been lacking; however, results from the few areas that have been monitored are encouraging enough to continue utilizing them. In the 2016 management season, a series of benthic barriers were installed where the infestation was a dense line right at the water's edge immediately upstream of a community water system in-take where neither herbicide use nor turbidity from the plant removal process were tolerable. Past experience has shown us the need to return annually to remove plants that escape around the edges or push their way up between seams.

Spread and Control of Flowering Rush in Lake Pend Oreille: Large Reservoir. Betsy l. Hull*; DOD-USACE, Oldtown, ID (122)

Flowering rush (*Butomus umbellatus L.),* an invasive aquatic plant, is rapidly spreading throughout the northern United States. In 2005 it was thought to inhabit only 6 counties in Montana and Idaho; however, rush now occurs throughout most of the Pend Oreille River Basin. Collaborative research efforts in Lake Pend Oreille, a 95,000-acre reservoir in northern Idaho, began in 2009 with the Idaho State Department of Agriculture (ISDA) coordinating with the United States Army Engineer Research and Development Center (ERDC) to control the plant. These trials included bare-ground applications using two herbicides and benthic barrier placement in 2010 on United States Army Corps of Engineer (USACE) lands at the Clark Fork Driftyard on the lake. Since that time, research and demonstration trials have been conducted with a number of partners (chemical companies, ISDA, ERDC, USACE, Bonner County Weed Department, and universities) to find a control mechanism for flowering rush. The system is very complex and strategies for research efforts and operational control of flowering rush in the system are challenging. Issues such as water management policy, the presence of Bull Trout - a listed species, required permitting, Federal National Environmental Policy Act (NEPA) requirements and multiple land owners will be reviewed. Further management to control flowering rush will need to address, and resolve, all of the issues.

Chemical Control of Flowering Rush in the Pacific Northwest: Field Trials. Kurt Getsinger*[1], John Madsen[2]; [1]USAERDC, Vicksburg, MS, [2]USDA-ARS, Davis, CA (123)

The invasive plant, flowering rush (*Butomus umbellatus* L), is spreading rapidly in Pacific Northwest waterbodies, including the Columbia River Basin. A series of field trials have been conducted to evaluate performance of several herbicides against flowering rush in Lake Pend Oreille, ID, in the lower Clark Fork basin. Results will be used to improve application techniques, timing of applications, long-term efficacy, and restoration of native vegetation to improve fish and wildlife habitat. Trials have included in-water applications of the herbicides fluridone and triclopyr (1-acre plot, Drift Yard Site, August 2013), and diquat (10-acre plot, Oden Bay Site, August 2016), and applications of imazapyr, imazamox, and 2,4-D to de-watered areas (0.25-acre plots, Drift Yard Site, August 2015). Pre and post-treatment (6 and 52 weeks) efficacy assessments were conducted on herbicide-treated and untread plots. At 52-weeks after treatments with triclopyr (2500 ppb) and fluridone (60-90 ppb), flowering rush control was > 70 % compared to pretreatment levels. Application of diquat (2 gal/surface acre) provided > 909 % control of flowering rush in the treated plot by five weeks after treatement. In-water applications were performed in August to ensure that water temperatures in the plots exceeded 18 C, which precluded the occurrence of bull trout (a listed species) in the treatment area. Flowering rush shoot mass in de-watered applications declined by 60-80 % at 52 weeks post-treatment. However, re-growth of shoots was substantial at 68 weeks post-treatment, compared to 16 weeks post-treatment. Data collected to date, and observations on operational-scale applications using the same products in adjacent areas of Oden Bay, indicate that two consecutive years of applications may be required for adequate control of flowering rush in de-watered sites. Concurrent studies are underway lining weak points in the flowering rush life cycle to application parameters to provide more consistent and prolonged control of the plant.

Is Biocontrol a Future Management Option for Flowering Rush? Jennifer E. Andreas*[1], Patrick Haefliger[2], Hariet Hinz[2], Jenifer Parsons[3], Greg Haubrich[4], Peter M. Rice[5]; [1]Washington State University Extension, Puyallup, WA, [2]CABI Europe-Switzerland, Delemont, Switzerland, [3]Washington Department of Ecology, Yakima, WA, [4]Washington State Department of Agriculture, Yakima, WA, [5]University of Montana, Missoula, MT (124)

Flowering rush, *Butomus umbellatus* L., is an aggressive invasive plant that rapidly colonizes freshwater aquatic systems. It is becoming an increasing concern in many North American states and provinces and is poised to become a substantial problem in several major waterways, despite ongoing eradication efforts. Although appropriate chemical and mechanical control methods continue to be explored, they have thus far been relatively ineffective, creating concerns that the flowering rush populations will continue to expand and spread without restriction. In looking for possible alternative control methods, the Flowering Rush Biocontrol Consortium (FRBC) was formed and a biocontrol research and development program was initiated in 2013. Flowering rush is an excellent candidate for biocontrol because it is the sole genus and species within the family Butomaceae. This increases the probability of finding a host-specific biocontrol agent, and likely reduces the number of test plant species required for host-specificity testing. The FRBC consists of many state and provincial partners that have pooled resources to fund CABI Europe-Switzerland to conduct field surveys, host-specificity tests, and impact studies of potential biocontrol agents. Within three years CABI has identified several potential insects and a pathogen. Host-specificity testing has begun for the rhizome- and leaf-mining weevil, *Bagous nodulosus*, with very promising results; of 35 test plant species, only flowering rush has been accepted by *B. nodulosus* during sequential no-choice oviposition tests.

Integrated Pest Management Opportunities for Flowering Rush - A Discussion. Amy P. Ferriter*; Crop Production Services, Boise, ID (125)

This timeslot is an opportunity for Flowering Rush session participants to discuss Integrated Pest Management (IPM) options for detection and control of Flowering Rush in the Pacific Northwest. The group will also discuss available control and management priorities.

WAPMS Business Meeting. Amy P. Ferriter*; Crop Production Services, Boise, ID (126)

This is the Business Meeting of WAPMS. All meeting participants are encouraged to attend and participate!

Genetic variation and management of Eurasian watermilfoil. Ryan A. Thum*; Montana State University, Bozeman, MT (141)

Genetic variation has not historically been a focus of traditional aquatic plant management. There are few published studies of molecular or heritable phenotypic variation for widely managed aquatic plant species in the United States. Yet, the few studies that have been published reveal that managed aquatic plant taxa can exhibit cryptic taxonomic variation and heritable phenotypic variation, both of which can be relevant to management issues such as potential for growth, spread, impact, and control. Here, I will present data on genetic variation in the widely distributed and managed invasive aquatic plant, Eurasian watermilfoil (*Myriophyllum spicatum* L.). I will show that what is considered Eurasian watermilfoil *sensu lato* by aquatic plant managers is actually a cryptic complex of at least two distinct biotypes of pure Eurasian watermilfoil and numerous genotypes of hybrids with native northern watermilfoil (*Myriophyllum sibiricum* Komarov). I will also show that hybrid watermilfoil can grow and respond to herbicides differently than pure Eurasian watermilfoil, and that the relative abundance of pure and hybrid watermilfoil can change over time in managed lakes. In addition, I will show that vegetative growth rate is heritable among distinct genotypes of hybrid watermilfoil, which in turn may influence dynamics of growth, spread, and control of populations over time. There is much more to learn about the degree and relevance of genetic variation in invasive (and native) aquatic plants. I encourage aquatic plant managers to include studies of genetic variation whenever possible, including detailed temporal monitoring of molecular and phenotypic variation.

Control Efforts of Invasive Watermilfoil in Noxon Reservoir, MT. Kim Bergstrom*; Sanders County Aquatic Invasive Plants Task Force, Thompson Falls, MT (142)

Eurasian watermilfoil (EWM) was discovered in Noxon Reservoir, Montana, a decade ago (2007) and the Sanders County Aquatic Invasive Plants Task Force has faced the challenge of treating and managing the invasive plant head on. With a diverse shoreline that includes public waterway access and private properties and docks, littoral zones that are ideal for aquatic plant growth, variable water exchange and ever-changing environmental conditions, uncertainty in funding availability, and the recent discovery of hybrid watermilfoil in the system, the management program has adapted time and again to address new and emerging needs for treating and containing EWM in this run-of-the-river system. In spite of set-backs experienced and lessons learned the hard way, treatments have effectively kept EWM at a level far lower than what would have been anticipated had no management or treatment been conducted at all.

Eradication of Eurasian watermilfoil in Beaver Lake, MT by diver dredge. Erik Hanson*; Hanson Environmental, Missoula, MT (143)

Beaver Lake is a 144 acre lake in Northwestern Montana. Eurasian watermilfoil was discovered in the fall of 2011. A large patch was identified next to the boat launch and a visual survey found no other patches. Bottom Barriers were placed over the patch. Starting in 2012, the entire littoral zone was snorkel surveyed and any Eurasian watermifoil was removed by diver dredge. Several minor patches and scattered plants were found and removed. By 2015, only ten plants were removed and in 2016 five plants were removed. It is expected that we will achieve eradication in 2017.

Twin Falls County: Aquatic Weed Challenges. Kali Sherrill*; Twin Falls County, Murtaugh, ID (144)

Abstract not available

Hydrilla Eradication in Idaho. Bethany Muffley*[1], Thomas Woolf[2]; [1]Idaho State Department of Agriculture, Boise, ID, [2]Idaho Department of Agriculture, Hayden, ID (145)

Hydrilla (*Hydrilla verticillata*) is one of the most aggressive and environmentally disruptive aquatic plants in the world. Due to these characteristics, the identification of hydrilla in Idaho is of particular regional concern for its potential to spread downstream into the Snake and Columbia River systems. Idaho hydrilla populations are currently contained within geothermally influenced areas; however, with the highly adaptable nature of this aquatic invasive, there is concern that temperature-based containment may not always apply. The Idaho State Department of Agriculture (ISDA) has been conducting an aggressive eradication program on hydrilla populations since its first discovery in 2007 in Owyhee and Ada Counties. Additional populations were identified in 2015 within Twin Falls County on a routine survey. Integrated pest management (IPM) efforts initiated from the beginning have included the use of chemical, mechanical, manual, and biological controls. Significant progress has been observed in the Owyhee County population with decreases above 95%, and Ada County was free of hydrilla for the first time in 2016. Removal efforts in Twin Falls County are currently underway and following the same IPM approach. Persistence has been key in the successful reduction of populations, and through a focus and sustained effort, substantial progress is expected to continue until eradication is achieved.

Short Duration Teton Slug Treatments in Irrigation Canal Systems: SCBID Trial Treatments. Cory Greer*; South Columbia Basin Irrigation District, Mesa, WA (146)

Invasive aquatic weeds and algae pose a great risk to irrigation system waterways where continued drought in the PNW has pushed these systems to capacity on a continuous basis. Mechanical removal of invasive vegetation and algae is not cost effective and with thousands of miles of canals and waterways, long term solutions are needed. Vegetative management in the canal systems have always included some chemical herbicide and algaecide component. The goal of all irrigation districts is to reduce chemical loading to their systems and to the environment. This is not only a sound environmental stance, it is also a sound business plan to reduce dollars spent on herbicides and algaecides. The South Columbia Basin Irrigation District (SCBID) has been a leader in implementing new principles for chemical applications to control vascular and algae growth within their irrigation delivery network. One of these new principles includes using Teton (Mono(N,N-dimethylalkylamine) salt of Endothall) in very short durations to replace copper and Acrolein (Magnecide-H) applications. The short duration applications have the potential to lower overall copper loading to the irrigation canals and environment and reduce the use of complicated Acrolein applications for small and medium canals. Results show that these intermittent, short duration, applications can extend time between larger needed treatments for both algae and invasive vascular submerged plants. This management plan can reduce the overall number of applications on some canal laterals and reduce total chemical usage as part of a system wide vegetative management plan.

Technical status of invasive watermilfoil management in the US and future outlook for improved control practices. Scott Shuler*, Mark A. Heilman; SePRO Corporation, Carmel, IN (149)

Eurasian watermilfoil (*Myriophyllum spicatum*), its hybrids and other non-native watermilfoils have infested many areas of North America with major impacts to aquatic ecosystems and their ecological and economic value. Among various integrated practices, the use of aquatic herbicides has provided resource managers reliable means to manage problem watermilfoils at both small and large scale. However, aquatic herbicide management of invasive watermilfoil is faced with increasing regulatory requirements and technical challenges, and therefore management strategies must continue to improve for better long-term sustainable control. Invasive watermilfoil management with aquatic herbicides has seen an evolution of older technologies and their refinement for improved use. Recent efforts have also seen the development of newer technologies and methods that offer greater selectivity for control through less impact to desirable native aquatic plants and potential for reduced risk to human health and the environment. In this paper, a concise review of past herbicide management history for invasive watermilfoils will be provided along with overview of new strategies such as various combination approaches, pelleted formulation use of SONAR® for partial site management, and the potential future fit of PROCELLACOR™. Recent development efforts will be put in context with past herbicide management strategies to suggest possible best management strategies for invasive watermilfoils looking into the future. Such strategies may include herbicide rotations/combinations, revisiting eradication strategies for new and established infestations, and techniques for management in challenging conditions such as high-exchange.

Translocation of ^{14}C-Endothall in Eurasian Watermilfoil and Two Hydrilla Biotypes. Mirella Ortiz*[1], Scott Nissen[1], Kallie Kessler[1], Cody Gray[2]; [1]Colorado State University, Fort Collins, CO, [2]UPI, Fort Collins, CO (150)

In 1960 endothall was labeled for aquatic weed control in lakes, and in 2010 the endothall label was expanded to include aquatic weed control in flowing water. Endothall is generally considered a contact herbicide; however, many field observations suggest that it could have some systemic activity. We hypothesize that endothall can translocate in Eurasian watermilfoil (EWM), monoecious hydrilla, and dioecious hydrilla. EWM shoots were collected from a local population and propagated by collecting 15 cm apical shoots and inserting the cut end into field soil. After two weeks, EWM plants with the most developed roots were transferred to test tubes containing fine, washed sand. A low melting point wax was used to seal the top of the test tube to isolate the root system from the water column. Monoecious and dioecious hydrilla plants were propagated from tubers and transferred to test tubes as previously described. EWM and hydrilla plants were transferred to four-liter mesocosms filled with tap water and allowed to equilibrate for 48 h. Mesocosms were then treated with 2 ppm endothall as the potassium salt plus 66 KBq ^{14}C-endothall. Plants were randomly selected for harvest over a 192 hour time course. At predetermined time points three EWM, dioecious hydrilla, and monecious hydrilla plants were harvested, divided into shoot and root tissue, dried at 60C for 48 h, and oxidized. Radioactivity in each plant part was determined by liquid scintillation spectroscopy. Data were subjected to non-linear regression analysis to determine maximum absorption and absorption rate. Monoecious and dioecious hydrilla plants showed a linear increase in herbicide absorption by shoots, while EWM plants showed a hyperbolic increase. Herbicide translocation to EWM roots was very limited, reaching a maximum translocation of 11% of total absorbed radioactivity in the first 48 hours after treatment (HAT). Monoecious and dioecious hydrilla plants showed a linear increase without reaching maximum translocation 192 HAT (distribution was 72/28 for monoecious and 75/25 for dioecious plants).

Evaluations of PROCELLACOR™ for future selective herbicide management of invasive watermilfoils and other Western US aquatic invasive plants. Mark A. Heilman*[1], Michael D. Netherland[2], Jens P. Beets[3], Amy P. Smagula[4], Ben E. Willis[5]; [1]SePRO Corporation, Carmel, IN,

[2]USAERDC, Gainesville, FL, [3]University of Florida, Gainesville, FL, [4]New Hampshire Department of Environmental Services, Concord, NH, [5]SePRO Corporation, Whitakers, NC (151)

PROCELLACOR™ is a novel herbicide technology under development for aquatic use and anticipated for USEPA approval in spring 2017. PROCELLACOR has unique, low-rate, systemic activity for selective control of the major submersed weeds hydrilla (*Hydrilla verticillata*) and Eurasian watermilfoil (*Myriophyllum spicatum - EWM*), including Eurasian X Northern (*M. sibiricum - HWM*) hybrid watermilfoils. It also has excellent activity on other invasive/nuisance watermilfoils such as variable watermilfoil (*M. heterophyllum*) and parrotfeather (*M. aquaticum*). It shows good selectivity to native submersed vegetation such as tapegrass (*Vallisneria americana*), common waterweed (*Elodea canadensis*), and pondweeds (*Potamogeton* spp.). It also has selective foliar activity for treatment of certain floating/emergent invasive and nuisance aquatic plants such as water hyacinth (*Eichhornia crassipes*), floating hearts (*Nymphoides s*pp.), and primrose (*Ludwigia* spp.). In studies for registration, PROCELLACOR shows no mammalian toxicity and an excellent environmental profile for use in water. This paper will focus on 1) 2016 large outdoor mesocosm trials documenting response of established EWM, a highly 2,4-D tolerant HWM, and several representative northern native submersed plants to PROCELLACOR and 2) a summary of other recent laboratory and field trials documenting activity on invasive watermilfoils and other aquatic weed species managed in the western US. For the large mesocosm work, testing of 3, 9, and 27 ppb PROCELLACOR with short exposure scenarios indicative of spot (6-hour dilution half-life) or partial (24-hour dilution half-life) and static exposures documented full control of established EWM and HWM with short exposures with slightly reduced response by the 2,4-D tolerant HWM and minimal effects to 6 representative native submersed plants included in the study.

Evaluating Efficacy of Endothall Treatment on Eurasian and Hybrid Watermilfoil in Jefferson Slough, Montana. Paula Guastello*, Ryan A. Thum; Montana State University, Bozeman, MT (152)

Eurasian watermilfoil (*Myriophyllum spicatum*) is a heavily managed aquatic invasive species that impedes waterbody uses. Eurasian watermilfoil hybridizes with its native sister species, northern watermilfoil (*M. sibiricum*). Resulting hybrids are an emerging concern for aquatic plant managers, because some hybrid genotypes exhibit faster vegetative growth and/or reduced herbicide response. However, direct comparisons of pure versus hybrid genotypes are currently limited. In this study, we evaluate the potential to control nuisance pure and hybrid Eurasian watermilfoil with endothall in a riverine environment (Jefferson Slough, Montana). First, we compared vegetative growth and endothall response of hybrid and Eurasian watermilfoil in the greenhouse. We did not identify any clear difference in response to endothall by hybrids versus pure Eurasian watermilfoil in the greenhouse. However, hybrids exhibited faster vegetative growth rates in the absence of endothall. Next, we evaluated the efficacy of an operational endothall treatment in Jefferson Slough. Similar to the greenhouse study, hybrid and Eurasian watermilfoil were reduced to the same average abundance after endothall treatment in the Slough. Therefore, we did not find any evidence that hybrid watermilfoil is inherently more tolerant to endothall in

Jefferson Slough. However, post-treatment, we observed a qualitative increase in relative frequency of occurrence of hybrids in the section of the Slough where pure and hybrid Eurasian watermilfoil overlapped pre-treatment. This observation, along with the faster hybrid growth rates in the greenhouse, may indicate subtle differences in the relative rate of re-growth and re-establishment of hybrid versus pure Eurasian watermilfoil in the field.

Procellacor: concentration exposure time trials. Erika J. Haug*, Rob Richardson; North Carolina State University, Raleigh, NC (153)

The herbicide Procellacor is a new arylpicolinate herbicide currently under development for weed management in rice (*Oryza sativa* L.) production, aquatic weed management, and other uses. Mesocosm trials were conducted at NC State University to evaluate the effect of the compound on several native and non-native aquatic plant species Specifically, this study focused on elodea (*Elodea canadensis*), coontail (*Ceratophyllum demersum*), tapegrass (*Vallisneria americana*), monoecious hydrilla (*Hydrilla verticillata*), and Eurasian watermilfoil (*Myriophyllum spicatum*). Plants were planted in October of 2015 and allowed to overwinter and establish in 200 gallon, lined mesocosms for eight months prior to treatment. Treatment rates included 6.25 ppb, 12.5 ppb, 25 ppb and 50 ppb. Exposures ranged from 6 to 72 hours. Eurasian watermilfoil was completely controlled at all concentration exposure time combinations. Monoecious hydrilla showed sensitivity at the higher rates and exposure times. Coontail was sensitive to Procellacor at the longer exposure times. Tapegrass and elodea showed limited sensitivity and symptomology throughout the trial. Overall, this new product to the aquatic industry appears to provide effective control of some of the most troublesome invasive aquatic plants, while having limited impact on some native species.

Dissolved phosphorus enrichment for the suppression of Didymo (*Didymosphenia geminata*) nuisance mats in the Kootenai River, Libby, MT. Mary K Vivian*, Frank M. Wilhelm; University of Idaho, Moscow, ID (154)

Nuisance mats of *Didymosphenia geminata* have occurred in the Kootenai River near Libby, Montana since the early 2000s. In stressed environmental conditions, this diatom produces mucopolysaccharide stalks in excess, forming nuisance mats along the benthos of lotic systems. At nuisance levels, mats degrade the aesthetic and recreational values and ecological functions of rivers. As part of a follow-up study to a series of mesocosm experiments in which the addition of phosphorus resulted in reduced stalk lengths, an in-river dissolved phosphorus (P) enrichment was completed in the spring of 2014 to test the hypothesis that the addition of phosphorus at the river scale would reduce the nuisance mat coverage. The addition of 108.41 kg of struvite (CrystalGreen^{TM}) over 18 days of increased the available phosphorus by approximately 0.8 µg/L above ambient river concentrations. After 14 days, P enrichment significantly suppressed mat depth and coverage for ~300 m downstream of the release site and resulted in nuisance mat detachment in several areas. These results suggest that P enrichment is a potential management strategy for nuisance mats in oligotrophic lotic systems. Because no whole-river management policies exist currently for *D. geminata* nuisance mats in river systems with important fisheries, this study provides a starting point to examine this potential strategy.

Washington State Department of Ecology's Harmful Algal Blooms (HAB) program. Lizbeth Seebacher*; Washington Department of Ecology, Olympia, WA (155)

Cyanobacteria (blue-green algae) can be toxic and toxic blooms are becoming more common in the Pacific Northwest. Ecology's Freshwater Algae (HABs) Program offers local governments with the tools they need to manage this growing problem. We provide a competitive grant program and an algae monitoring and toxicity testing program along with the associated Washington State Toxic Algae website and database. In partnership with the Washington State Department of Health, we also provide local agencies a protocol to follow and recommended toxicity levels for recreational activities for four of the most common toxins. I will also discuss some of the significant research we have funded through this program.

PROJECT 1: WEEDS OF RANGE AND NATURAL AREAS

Four-year Survival and Growth Responses of Planted Douglas-fir to Logging Debris and Herbicide Treatments. Timothy B. Harrington*[1], David H. Peter[2], Robert A. Slesak[3]; [1]USDA Forest Service, Olympia, WA, [2]U.S. Forest Service, Olympia, WA, [3]University of Minnesota, Minneapolis, MN (106)

Logging debris has the potential to benefit forest regeneration by modifying microclimate and inhibiting competing vegetation. At a recently harvested forest site near Matlock WA, two operational logging debris treatments (20 and 9 Mg ha^{-1} of debris, designated as "heavy debris" and "light debris," respectively) were replicated six times as main plots in a split-plot design. Split plots included three site-preparation herbicide treatments (aminopyralid (A), triclopyr ester (T), and A+T) and a non-sprayed check. The debris treatments were applied in December 2011, the herbicide treatments were applied in August 2012, and Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) seedlings were planted in February 2013. Soils are coarse-textured gravelly sands of moderate forest productivity formed from glacial outwash. During September and October of 2012 (prior to Douglas-fir planting), soil water content was greater in A+T than in the non-sprayed check. During the growing seasons of 2012-2014, soil water content was higher and soil temperature was lower under heavy debris than under light debris. First-year (2013) incidence of Douglas-fir chlorosis (i.e., yellowing of foliage indicative of nitrogen deficiency) was lowest in heavy debris plus triclopyr (1% of seedlings) and it was highest in light debris treatments (13-14%) except where A+T was applied (9%). Douglas-fir survival declined 45 and 11 percentage points after the summer droughts of 2015 and 2016, respectively, and during 2014-2016 it averaged 7-10 percentage points greater in heavy debris than in light debris. Development of Douglas-fir stem diameter was more uniform and rapid in heavy debris than in light debris, with the exception of A+T where development did not differ between debris treatments. Douglas-fir height was 11-15 cm greater in heavy debris than in light debris during 2014-2016. A competition threshold model (R^2=0.55) predicted decreases in total stem volume per plot of Douglas-fir up to 80% as cover of Scotch broom (*Cytisus scoparius*) increased from 0 to 20%. These results suggest that, on glacial-origin soils and possibly other droughty forest ecosystems in the Pacific Northwest, a heavy debris treatment will benefit planted Douglas-fir by improving growing conditions (i.e., increased soil water and decreased soil temperature) and by limiting abundance of nonnative competitors, such as Scotch broom.

Differences in Plant Community Assembly of a Western Washington Forest Five Years after Harvesting with Various Combinations of Logging Debris Retention and Vegetation Control. David H. Peter*[1], Timothy B. Harrington[2]; [1]US Forest Service, Olympia, WA, [2]USDA Forest Service, Olympia, WA (107)

We examined plant community organization over the first 5 growing seasons following clearcut logging under two levels of logging debris (9 or 20 Mg ha^{-1}) and 4 vegetation control treatments (none, aminopyralid, triclopyr, and aminopyralid + triclopyr). The study site was 47 km northwest of Olympia, WA, and before clearcutting had a Douglas-fir overstory with salal and bracken fern in the understory. We used a randomized split plot experimental design replicated in 6 blocks (each main plot had one of 2 debris treatments and 4 split plot herbicide treatments). We estimated percent canopy cover by species before clearcutting and in post-harvest seasons 1-3 and 5 on 100 m^2 plots located within each split plot. We used ANOVA to examine annual treatment effects on major species and species groups. Abundance of ruderal species, especially exotics, was lower but abundance of native woody shrubs and vines was greater in heavy debris than in light debris. The vine group (mainly trailing blackberry) developed higher cover in heavy debris where it used the debris as a scaffold to gain a competitive advantage over other species. Heavy debris controlled Scotch broom better than the herbicides. Triclopyr reduced woody dicots, vines and native herbs, while aminopyralid reduced these groups and Scotch broom, but aminopyralid had less effect on total canopy cover. The combination herbicide treatment reduced woody dicots, vines and Scotch broom, and had the biggest impact on total canopy cover. By year 5 there was little difference in total canopy cover among the herbicide treatments, however for some species, both debris and herbicide treatment effects were still emerging. We conclude that heavy debris is a viable treatment alternative to prevent aggressive exotic species from competing with planted conifers and the native plant community on edaphically dry sites in western Washington.

Incipient Weed Control: Protecting Watersheds One Plant at a Time with Extreme Prejudice. James Leary[1], Kimberly Burnett[2], Brooke V. Mahnken*[3], Chris Wada[2], Roberto Rodriguez[2]; [1]Univ of Hawaii, kula, HI, [2]Univ of Hawaii at Manoa, Honolulu, HI, [3]Maui Invasive Species Committee, Makawao, HI (108)

Miconia (*Miconia calvescens* DC) was introduced to East Maui as a single horticultural specimen circa 1970. Management commenced two decades later with a 25-year history that continues today. Our understanding of miconia phenology, fecundity and seed bank viability informs us that delays or lapses in management could lead to a breakdown of containment and eradication strategies. In 2012, Herbicide Ballistic Technology (HBT) was introduced as a novel treatment platform on manned helicopter surveillance missions; virtually doubling operational efficiency by combining intelligence gathering activities with concurrent target elimination. To date, over 100 HBT missions have been conducted, approaching 500 hours of operational flight time, treating over 20,000 high-value, incipient targets, serving to protect over 18,000 ha of the East Maui Watershed (EMW). These robust operations data allow us to explore performance analytics in a real management setting, e.g., search efficiency, herbicide use rate, etc., which can be further monetized to determine variable costs of an operation. Using GIS, we have calculated the dispersal kernel spread out to 1644 m that creates an impact area approaching 850 ha and is strongly corroborated by a similar probability density function for miconia dispersal in Australia. Our future goal is to use these new model parameters for optimizing containment strategies with most effective impact reduction and highest return on future cost avoidance. The successful adoption of HBT was achieved through a spontaneous form of participatory action research where scientists and practitioners shared in the responsibilities of research and management towards evolving solutions in landscape-level invasive species management.

Interactive Effects of Grazing, Glyphosate Rate, and Application Timing on Barb Goatgrass Seedhead Production and Viability. Travis M. Bean*[1], Josh Davy[2], Elise Gornish[3], Guy B. Kyser[4]; [1]University of California, Riverside, Riverside, CA, [2]University of California Cooperative Extension Tehama County, Red Bluff, CA, [3]University of California, Davis, Davis, CA, [4]University of California, Davis, CA (109)

Eurasian winter annual, barb goatgrass (*Aegilops triuncialis*), is increasing its range in western states dominated by cool season precipitation. As an ecosystem transformer, barb goatgrass can permanently degrade rangeland and natural areas, making it a management priority. Conventional management has been largely unsuccessful, due in part to the difficulty of selectively removing undesirable annual grasses from habitats dominated by other annual grasses. Barb goatgrass has been observed to mature later than desirable species. To take advantage of this apparent separation in phenology we implemented a field experiment in five pastures at the University of California Hopland Research and Extension Center in Hopland, CA. In March through May of 2016, we applied glyphosate (Roundup WeatherMax ®) to specific barb goatgrass phenological phases (tillering, boot, heading) at high (394 g ae ha^{-1}) and low (1261 g ae ha^{-1}) rates in combination with targeted grazing by sheep (32 sheep days in each 324-m^2 plot) at the boot stage. Our goal was to minimize seed production of barb goatgrass while minimizing negative impacts to desirable forage species by evaluating the integrated efficacy of targeted grazing with precisely timed nonselective herbicide application. Plots were surveyed for seedhead densities of barb goatgrass in June 2016. Grazing reduced overall barb goatgrass density by 68%. The presence of herbicide reduced barb goatgrass density by 60% overall, but no differences in density were found between low and high herbicide rates. Spraying goatgrass at the tiller stage resulted in a 99% decline in density compared to other phenological phases. Spraying at the boot stage resulted in a 10% decline in density compared to spraying at the heading stage. No interactions were found among grazing and herbicide rate or herbicide rate and phenological stage at the time of herbicide application.

Management of Downy Brome (Bromus tectorum) and Ventenata (Ventenata dubia) with Indaziflam in Washington and Idaho Grasslands. Lindsay E. Koby*[1], Timothy Prather[2], Ian C. Burke[1]; [1]Washington State University, Pullman, WA, [2]University of Idaho, Moscow, ID (110)

The Palouse prairie in Eastern Washington and Northern Idaho is a critically endangered ecosystem due to agriculture. Fragmented sections, called remnants, of native prairie are threatened by invasive species, thus requiring active management of these sites. Two such sites near Moscow, ID and Pullman, WA were chosen to evaluate indaziflam as a potential management option of invasive annual grasses. Downy brome and ventenata are prevalent weeds in perennial bunch grasses native to the Palouse. Prior to dormancy break of native grasses (Feb. 25, 2016 and March 21, 2016), the trials were treated with different formulations of indaziflam with tank mix partners and evaluated over time for level of control observed for weedy species and population densities of native species present. Control of ventenata was 69% and 84% when indaziflam was applied at two rates (73 or 102 g ai ha^{-1}), respectively, in mixture with glyphosate at 474 g ai ha^{-1} plus nonionic surfactant (0.25% v v^{-1}). Control of ventenata was >99.0% when indaziflam was applied with rimsulfuron plus nonionic surfactant 0.25% v v^{-1} respectively, in early June. Mixtures of indaziflam plus rimsulfuron are effective for management of annual invasive grasses in native prairie. Further observations will be conducted to gain an understanding of indaziflam persistence and impact of species diversity and distribution on native prairie species within these fragmented ecosystems.

Indaziflam: Changing the Way Invasive Winter Annual Grasses are Managed on Non-Cropland. Derek J. Sebastian*[1], Harry Quicke[2], Scott Nissen[3]; [1]Bayer CropScience, Fort Collins, CO, [2]Bayer CropScience, Windsor, CO, [3]Colorado State University, Fort Collins, CO (111)

Managing invasive winter annual grasses on non-crop and rangeland remains a constant challenge throughout many regions of the US. Currently, there are limited management options for controlling winter annual grasses that work consistently, provide multiple years of control, and do not injure desirable co-occurring species. Indaziflam (Esplanade™, Bayer CropScience) is a cellulose biosynthesis inhibiting (CBI) herbicide that is a unique mode of action for resistance management and has broad spectrum activity at low application rates (51 to 102 g·ai·ha^{-1}). Multiple studies have evaluated indaziflam's potential to control problematic invasive winter annual grasses found in the US and compared its activity to the most commonly used herbicide, imazapic. Indaziflam was recently labeled for the release or restoration of desirable vegetation in natural areas, open spaces, wildlife management areas, and fire rehabilitation areas. Indaziflam is unique in that is has been shown to provide long-term selective control (3+ years) of the most prevalent invasive winter annual grass in the US, downy brome (*Bromus tectorum* L.). Multiple studies have shown indaziflam provides superior invasive winter annual grass control (3+ years) compared to imazapic (1 year). Indaziflam also provides control of other invasive winter annual grasses including feral rye (*Secale cereale* L.), Japanese brome (*Bromus japonicus* Thunb. or *Bromus arvensis* L.), jointed goatgrass (*Aegilops cylindrica* L.), medusahead (*Taeniatherum caput-medusae* [L.] Nevski), and ventenata (*Ventenata dubia* (Leers) Coss). Indaziflam treatments have been shown to promote (release) the remnant perennial grass and forb plant communities and increase their resistance and resilience to future invasions. Indaziflam could potentially be used to eliminate the soil seed bank of these invasive grasses, decrease fine fuel accumulation, and ultimately increase the competitiveness of perennial co-occuring species.

Economic Impact of Noxious Weeds on Private Rangeland in Montana. Jane Mangold*[1], Kate Binzen-Fuller[1], Stacy Davis[1], Matthew Rinella[2]; [1]Montana State University, Bozeman, MT, [2]USDA-ARS, Miles City, MT (112)

Several studies in the 1990s evaluated the economic effect of noxious weeds on a statewide basis in Montana as well as other states. To update our understanding of these economic impacts, in winter 2015-16 we distributed a 16-question survey concerning noxious weed management and associated costs to livestock producers who were grazing their livestock on privately owned rangeland in Montana. We received 113 usable responses from 45 (out of 56 total) counties within Montana, with the majority of respondents grazing cattle, followed by sheep and horses. The average size of a grazing unit was 5,055 acres. The three noxious weeds reported as having the most effect on stocking rates were leafy spurge, Canada thistle, and knapweeds (spotted and diffuse). Seventy-four percent of respondents were directly responsible for noxious weed management on their grazing unit, whether they owned or leased the land. Using available empirical data, we estimated an average loss in forage biomass of 0.7% resulting from spotted knapweed, and 0.8% from leafy spurge. We estimated the corresponding value of the reduction in stocking rate to be $0.40 per acre, or $2,022 annually for the average size of a respondent's grazing unit. Using respondent-reported material costs and labor hours, we estimated that the average total cost of noxious weed prevention and control, including labor and materials, is $0.89 per acre, or $4,499 for the 5,055-acre average grazing unit size. The total cost, including the value of the foregone grazing, is $1.29 per acre per year, or $6,521 annually for an average grazing unit; this translates to $828,234 for all of the grazing land reported in our sample.

Rimsulfuron and Imazapic Interception and Sorption by Downy Brome, Medusahead, and Ventenata Residue. Shannon L. Clark*[1], Paulo V. Da Silva[2], Derek J. Sebastian[3], Scott Nissen[1]; [1]Colorado State University, Fort Collins, CO, [2]Universidade de Sao Paulo/ESALQ, Piracicaba, Brazil, [3]Bayer CropScience, Fort Collins, CO (134)

Invasive winter annual grass species, including downy brome (*Bromus tectorum* L.), ventenata (*Ventenata dubia*), and medusahead (*Taeniatherum caput-medusae*), are all highly competitive, with downy brome being considered one of the most problematic invasive species in rangeland. One characteristic of these winter annual grass infestations is that large quantities of residue accumulate on the soil surface over time. This leaves thick layers of residue that herbicides must penetrate in order to reach the soil surface. Timely rainfall can desorb some herbicide from the residue, but little information is available about the efficiency of herbicide "rainoff". A lab experiment was conducted to first determine the proportion of rimsulfuron and imazapic intercepted by downy brome, ventenata, and medusahead residue; and determine the efficiency of simulated rainfall events to remove the intercepted herbicide from the residues. Residues were placed in wire baskets over Pyrex dishes and sprayed with a Generation III Research Track Sprayer (DeVries). Rimsulfuron and imazapic were applied at recommended field rates (0.0625 lb ai/A and 0.1 lb ai/A, subsequently) on 5.64g of residue, equivalent to 260 g/m^2 under field conditions. Samples were collected after spraying the herbicide to determine the amount intercepted by each residue. The residues were then "rained-off" immediately with simulated rainfall of 3mm, 6mm, and 12mm. A separate set of residue samples were "rained-off" 24hr after herbicide application with the same rainfall amounts. Results showed that between 65% and 82% of the rimsulfuron and imazapic was intercepted among the residue types. The effects of rainfall on imazapic and rimsulfuron desorption from downy brome, ventenata, and medusahead thatch showed that an initial rainfall event immediately after herbicide application resulted in 100% desorption of the rimsulfuron and imazapic from annual grass residue; however, 24hr after treatment desorption was only 60% for both rimsulfuron and imazapic at the highest rainfall amount (12mm). This research illustrates the impacts of residues on herbicide interception and the amount of herbicide removed by rainfall. Imazapic and rimsulfuron were harder to desorb from the residue when allowed to interact for 24hr before rainfall. Future research will examine longer periods between herbicide applications and rainfall and the impact of multiple rainfall events.

Co-invasions: Are Two Similar Invaders Worse than One? Daniel Tekiela*[1], Jacob N. Barney[2]; [1]University of Wyoming, Laramie, WY, [2]Virginia Tech, Blacksburg, WY (135)

The vast majority of impact studies focus on a single invader. However, many ecosystems are experiencing invasion from multiple species simultaneously. This is a major limitation when trying to understand the impacts of invasive plants in multi-invaded systems. Invasive plants of similar life history may interact in various ways that may facilitate further invasion – so called invasion meltdown. Here we measured multiple ecological metrics of two invasive grass species (*Microstegium vimineum* and *Oplismenus undulatifolius*) across a range of covers to identify the cover-impact relationship and identify their interactions,

We conducted our survey in Soldier's Delight Natural Area within Patapsco State Park, Maryland where *O. undulatifolius* is thought have initially been introduced in 1996 where *M. vimineum* is also abundant. We surveyed 162 $1m^2$ quadrats systematically randomized within the overlapping range of these two invasive grasses to ensure all combinations of cover of both species were well represented. We also performed a manipulative study removing one or both of the invader to measure individual impacts.

Our results show that although both species can reduce resident plant community richness by as much as 70%, there was no greater reduction in richness when both species were present. Instead we found greater *M. vimineum* dominance lead to greater reductions in richness. Of additional alarm, native species richness was more greatly reduced than other invader richness in the presences of the co-invasion. This outcome could negatively impact the health of eastern forest ecosystems.

Vernalization Effects on the Translocation of Aminopyralid and Clopyralid in Rush Skeletonweed (*Chondrilla juncea* L.). Tara Burke*, Alan J. Raeder, Ian C. Burke; Washington State University, Pullman, WA (136)

The growth stage of perennial weeds can have a profound impact on transport of herbicides to above and below ground perennial survival structures and growing points. Rush skeletonweed (*Chondrilla junceae* L.), a problematic weed of rangelands, agricultural fields, and roadsides in the Pacific Northwest, is such a perennial weed. In field research on rush skeletonweed, applications of growth regulating herbicides can be more effective in fall applications compared to spring applications, suggesting that vernalization in rush skeletonweed can have an impact on herbicide absorption and translocation. Therefore, the objectives of this research was to quantify absorption and translocation of clopyralid and aminopyralid to non-vernalized and vernalized rush skeletonweed. Both vernalized and non-vernalized rush skeletonweed plants were treated with an overspray application of either clopyralid or aminopyralid with the youngest unfurled leaf covered; the covered leaf was subsequently treated with ^{14}C clopyralid or aminopyralid, respectively. Plants were then harvested into sections at five intervals. Absorption increased over time and was greater for non-vernalized compared to vernalized rush skeletonweed plants. For clopyralid, translocation to the belowground tissue was decreased following vernalization (66% reduction at 72 hours). In contrast, translocation to the belowground tissue was increased following vernalization for plants treated with aminopyralid (35% reduction at 72 hours). Absorption and translocation of clopyralid and aminopyralid were affected by vernalization and time.

Revealing the Distribution and Indicators of *Ventenata dubia* Invasion in Sagebrush Steppe Rangelands. Lisa C. Jones*[1], Nicholas Norton[2], Timothy Prather[1]; [1]University of Idaho, Moscow, ID, [2]Palouse Land Trust, Moscow, ID (137)

Ventenata (*Ventenata dubia*), an exotic winter annual grass, is an emerging problem in the Inland Northwest where it significantly reduces forage production in pasture and grassland systems and displaces both perennial and annual dominated grasslands. The range of ventenata is expanding into the sagebrush steppe, an expansive area critical for livestock forage production and wildlife habitat. Currently, there is limited knowledge of its distribution and abundance in this ecosystem. We performed field surveys at 15 sites in the sagebrush steppe in southern Idaho and eastern Oregon to assess, at both regional and local scales, where ventenata may become a serious problem as its range expands. We correlated species diversity measures with no, low (<12.5% foliar cover), and high (>12.5% foliar cover) ventenata cover. In addition, we evaluated biotic and abiotic factors of the plant community as indicators of ventenata presence. Though widely distributed throughout the study region, ventenata only appeared in 55% of the 225 plots across all sites and foliar cover was typically less than 50%. Non-metric multidimensional scaling species analysis revealed that ventenata and medusahead wildrye (*Taeniatherum caput-medusae*) were closely associated.

Abiotic factors that explained variation in ventenata abundance included rock cover, soil depth, and a north/south aspect. Higher ventenata cover also tended to correlate with phosphorus-deficient and finer-textured soils. Chi-squared indicator analysis showed that medusahead wildrye was overrepresented, while big sagebrush (*Artemisia tridentata*) was underrepresented, in plots containing ventenata. These findings indicate that in the sagebrush steppe, ventenata is in the early phase of invasion. At this stage, it is associated with medusahead wildrye and so detection survey efforts to locate incipient infestations should focus on sites susceptible to invasion by medusahead wildrye.

Evaluating the Use of Thresholds Concepts for Improving Habitat through Downy Brome Management. Clay W. Wood*[1], Brian A. Mealor[2]; [1]University of Wyoming, Laramie, WY, [2]University of Wyoming, Sheridan, WY (138)

Invasive species have an ever-increasing impact on the ecological and economic functions of ecosystems. Downy brome (*Bromus tectorum*) is an invasive annual grass that is widely distributed throughout most of the western United States. Downy brome produces high amounts of fine fuels that can increase fire frequency and severity, altering vegetation composition and structure. Although downy brome can be used as early spring forage for livestock and wildlife, it may not be preferred, and therefore its suitability as a forage is questionable. The objective of this research is to determine if there is a direct, predictable relationship between pre-treatment vegetation condition and post-treatment increases in perennial grass biomass and other vegetation characteristics following treatment with two formulations of imazapic (liquid and granular). We sampled locations representing a gradient of downy brome to perennial grass biomass and canopy cover ratios prior to, and following, herbicide application across multiple sites. We employed four different vegetation sampling methods to determine the ratio of downy brome to perennial grass using both biomass and cover. At the Saratoga and Pinedale, Wyoming field sites, we collected pre-treatment data in 2015, aerially applied herbicides in September 2015, and collected post-treatment data in 2016. Initial post-treatment results indicate that both herbicide formulations reduced downy brome cover. Preliminary data analyses suggest the ability to identify downy brome abundances at which an increase in perennial grass biomass in response to herbicide treatment may be expected, but inter-annual variability in vegetation poses challenges. Post-treatment data will be collected on all sites in 2017, including two additional field sites near Sheridan and Hyattville, Wyoming sampled and treated in 2016, to further evaluate the response of downy brome and associated vegetation following imazapic application.

Can Diet Training Increase Cattle Use of Spotted Knapweed? Jeffrey C. Mosley*[1], Brent L. Roeder[2], T. Rene Kittle[3], Jodi L. Pauley[4], Jane M. Mangold[1], Tracy K. Mosley[5], Daniel E. Lucas[6], Gerald Marks[7]; [1]Montana State University Extension, Bozeman, MT, [2]Montana State University Extension, Choteau, MT, [3]Montana State University Extension, Polson, MT, [4]Montana State University Extension, Deer Lodge, MT, [5]Montana State University Extension, Livingston, MT, [6]Montana State University Extension, Philipsburg, MT, [7]Montana State University Extension, Missoula, MT (139)

We investigated whether diet training (a.k.a., diet conditioning) would increase cattle use of spotted knapweed (*Centaurea stoebe*) and increase the efficacy of targeted cattle grazing to suppress this invasive perennial forb. We applied targeted cattle grazing for three consecutive years to spotted knapweed-infested rangeland in northwestern Montana, USA. Cattle simultaneously grazed within six, 1.3-ha pastures at a moderate stocking rate and low stock density during late July-early August (spotted knapweed in late bud-early flower phenotypic stage). Three yearling Angus heifers grazed within each pasture for 15 days in 2013 and 2014 and 12 days during the 2015 drought. Cattle in our study had no previous experience eating spotted knapweed before arrival at our study site. Each year, three pastures were grazed by untrained cattle, whereas three pastures were grazed by cattle trained to eat spotted knapweed. Immediately preceding each year's targeted grazing trial, cattle in the trained treatment were systematically introduced to novel and nutritious foods (cracked corn, rolled barley, wheat bran, and others) for four days, followed by six days in which cattle were gradually introduced to spotted knapweed to encourage its consumption during the grazing trial. Our results revealed that diet training did not affect any of the response variables we sampled ($P > 0.10$). Cattle diets averaged 10% spotted knapweed and 38% graminoids; forage utilization averaged 38% and 56% for spotted knapweed and perennial graminoids, respectively; neither trained cattle nor untrained cattle preferred eating spotted knapweed (preference index = 0.45); and cattle grazing averaged 85% removal of spotted knapweed buds, flowers, and seed-heads. After three years of treatment, targeted cattle grazing reduced spotted knapweed plant density 68%, but diet training provided no additional benefit.

Plant Community Response to Aminocyclopyrachlor. Peter M. Rice*; University of Montana, Missoula, MT (140)

Four replicated plot studies of weed infested native bunchgrass communities quantified the non-target plant and community level responses to aminocyclopyrachlor alone and in combination with chlorsulfuron or 2,4-D. Target weeds were spotted knapweed, leafy spurge, and dalmatian toadflax. Aminocyclopyrachlor rates ranged from 0.5 to 2.0 oz ai/A, chlorsulfuron at 0.17 to 0.75 oz ai/A, and 2,4-D at 7.6 and 12.7 oz ai/A. Treatments were done in the fall and spring. The Daubenmire canopy cover microplot method was used to gather response date for all plant species. Pre-spray sampling data provide a covariate term for ANCOVA followed by using Dunnett's and LSD pairwise comparisons of interest. Spotted knapweed control was 88 to 99% 1 YAT and 44 to 58% 2 YAT. At the MPG site leafy spurge control was 66 to 93% 1 YAT and -69 to 59% 3 YAT. At the COX site leafy spurge control was 52 to 90% 1 YAT and -12 to 29% 2 YAT. Dalmatian toadflax control was 34 to 91% 1 YAT and -3 to 71% 2 YAT. At MPG there were no significant ($p<0.10$) increases in canopy cover of any bunchgrass species as inferred by indicator species analysis. Combined perennial grass canopy cover did not increase post-spray on the other study sites with one short term exception at 1 YAT. However cheatgrass was a significant increaser in many cases. Species richness was markedly reduced one year after spraying, but then recovered somewhat in the second and third years. In spite of recovery in species numbers indicators species analysis based on canopy cover showed that non-target decreaser species still greatly exceeded increasers nominally and at $p<0.10$ at 3 YAT. Antelope bitterbrush was severely impacted. The percentage reduction of antelope bitterbrush 1 YAT relative to no spray controls ranged from 77 to 95%. Broadcast spraying of aminocyclopyrachlor formulations appear to have little utility for conservation of native plants although these herbicides could be useful for spot spraying during early stages of invasion.

PROJECT 2: WEEDS OF HORTICULTURAL CROPS

Halauxifen-methyl: A New, Innovative Herbicide for Control of Broadleaf Weeds in Turfgrass. Vanelle F. Peterson*[1], Jamie M. Breuninger[2], Anita L. Alexander[3], Daniel D. Loughner[4]; [1]Dow AgroSciences, Fort Collins, CO, [2]Dow AgroSciences, Indianapolis, IN, [3]Dow AgroSciences, Lawrenceville, GA, [4]Dow AgroSciences, Lawrenceville, NJ (094)

Halauxifen-methyl (Arylex™) is a new herbicide for postemergent weed control in turfgrass, cereals and other crops and registrations for use on wheat and other cereal crops has been obtained in the U.S. and other countries around the world. Arylex is an innovative low-dose synthetic auxin (HRAC group O) herbicide and the first member of the new arylpicolinate class of chemistry, designed to provide unique attributes compared to other growth regulator herbicides. Arylex unique binding affinity in the cell nucleus differentiates it from previous synthetic auxin herbicides: Arylex demonstrates an affinity for the AFB5 auxin binding protein site of action in the cell nucleus of susceptible weeds.

Arylex provides consistent control of important broadleaf weeds in turf including common dandelion (*Taraxacum officinale*), narrow plantain (*Plantago lanceolata*), broadleaf plantain (*Plantago major*), common chickweed (*Stellaria media*), henbit (*Lamium amplexicaule*), and dollarweed (*Hydrocotyle sibthorpioides*). Trial work on both cool and warm season turf species including Kentucky bluegrass (*Poa pratensis*), perennial ryegrass (*Lolium perenne*) and tall fescue (*Festuca arundinacea*), bermudagrass (*Cynodon dactylon*), St. Augustinegrass (*Stenotaphrum secundatum*) and zoysiagrass (*Zoysia japonica*) has shown good turfgrass safety.

Arylex is effective at very low use rates of 10 g ae/ha and, due to its low vapor pressure, Arylex does not cause off-target damage to desirable broadleaf plantings through volatilization. Tree studies on many different species have shown that the Arylex can be used under the drip line without concern for off target injury. Arylex rapidly degrades in soils and plant tissues. Field and laboratory studies with Arylex were conducted at Purdue University, West Lafayette, IN and Woods End Research Laboratory, Mt. Vernon, ME to determine its fate in grass clippings and compost. It was determined that Arylex breaks down very quickly in turfgrass (DT_{50}=1.5 days) and has no significant or lasting herbicidal activity in compost. In November 2016, Dow AgroSciences submitted a request for registration to US EPA for Arylex containing formulations for use on turfgrass in both commercial and residential settings.

Soil Solarization for Weed Control in PNW Field Nurseries. Nami Wada*, Jennifer Parke, Carol Mallory-Smith; Oregon State University, Corvallis, OR (095)

Soil solarization has been used successfully to control weeds and soilborne pathogens in areas with high solar radiation. In marginally suitable climates, solarization has been used primarily in closed systems such as under greenhouses or double-tents. Recent improvements in horticultural plastic films increased the feasibility of solarization in field production nurseries in western Oregon or Washington by improving energy capture which increases soil temperature. In this study, we evaluated the effect of solarization on weeds in three tree seedling nurseries during summer 2016. Seeds of four weed species (*Amaranthus retroflexus, Poa annua, Polygonum pensilvanicum, Portulaca oleracea*) were buried at 5 and 10 cm depths in solarized and non-solarized beds. After 6 weeks, seeds were removed and tested for viability via germination and tetrazolium chloride tests. In all sites and both depths, solarization was most effective on *Polygonum pensilvanicum,* least effective on *Portulaca oleracea*, and resulted in increased dormancy of *Amaranthus retroflexus* compared to the non-solarized control. We counted emergence of naturally-occurring weed populations at one site in Oregon nine weeks after plastic removal. There was a reduction in total weed density from 5.26 in the control to 0.21 plants 0.25 m^{-2} ($P < .001$) in solarized beds. Solarization can be a viable option to manage weeds in these nurseries because tree seeds are sown in fall following solarization, with minimal disturbance to the soil. Solarization also can reduce herbicide inputs and hand weeding costs.

Biosolarization for Organic Vegetable Crop Production: Where Weed Management and Soil Health Meet. James J. Stapleton*[1], Christopher W. Simmons[2], Ruth M. Dahlquist-Willard[3], Yigal Achmon[2], Jesus D. Fernandez-Bayo[2], Jean S. VanderGheynst[2]; [1]University of California, Parlier, CA, [2]University of California - Davis, Davis, CA, [3]University of California, Fresno, CA (096)

Organic vegetable producers in the inland valleys of California have employed solarization and biosolarization as effective and sustainable alternatives to soil fumigation. Industry sources estimate annual usage in the Imperial Valley at 20,000+/- acres, mostly for weed management in leafy greens crops. New developments and research findings will be discussed.

References: (1) Achmon et al. (2016) Weed seed inactivation in soil mesocosms via biosolarization with mature compost and tomato processing waste amendments. Pest Management Science: DOI:10.1002/ps.4354. (2) Oldfield et al. (2016) A life cycle assessment of biosolarization as an option for tomato pomace utilization in California. Journal of Cleaner Production 141:146-156. (3) Stapleton (2016) Alternatives to pesticides in controlling pests and diseases. Acta Horticulturae 1140:165-168.

Evidences for Vacuolar Sequestration as Mechanism of Resistance to Paraquat in a Population of Italian Ryegrass from California. Caio Augusto Brunharo*, Bradley D. Hanson; UC Davis, Davis, CA (097)

Italian ryegrass (*Lolium perenne* L. *spp. multiflorum* (Lam.) Husnot) is a problem weed around the world. Recently, poor control of Italian ryegrass with paraquat was reported by orchard managers in California. We hypothesize that the low paraquat efficacy observed is due to the selection of a paraquat-resistant biotype. A susceptible (S) and a suspected paraquat-resistant biotype (PRHC) were studied. Greenhouse dose-response experiments were carried out to calculate the resistance index (RI = GR_{50R}/GR_{50S}) of PRHC. The absorption and translocation of ^{14}C-paraquat was quantified under light-manipulated laboratory conditions, and the possibility of paraquat metabolism was evaluated using HPLC-based analytical techniques. Inhibitors of plasmalemma- and tonoplast-localized transporter systems were used to selectively block paraquat intracellular movement. After exposure to the inhibitors, leaf segments were transferred to paraquat solutions and membrane integrity was assessed using an electrolyte leakage technique. The experimental designs were completely randomized designs with 4 to 5 replications. PRHC exhibited a GR_{50} of 2013 g a.i. ha^{-1} and biomass-based RI = 80, confirming resistance to paraquat. Although S had faster initial absorption, both biotypes had similar maximum absorption of ^{14}C-paraquat. Translocation of ^{14}C-paraquat out of the treated leaf was 3% in PRHC and 53% in S after an incubation period of 16h in dark followed by 14h in light. No paraquat metabolites were found. Pre-exposure of PRHC leaf segments to putrescine followed by incubation in paraquat solutions increased the electrolyte leakage in PRHC to levels similar to S, suggesting that the resistance mechanism is related to vacuolar sequestration of the herbicide.

Tolpyralate Efficacy and Utility in Sweet Corn and other Vegetable Crops. Ed Peachey*; Oregon State University, 97331, OR (098)

Research continues to find low-cost, triazine-free weed control options in non-transgenic sweet corn production in W OR. Tolpyralate is a relatively new HPPD herbicide developed by ISK with selectivity in corn and possibly vegetable crops. Crop safety and efficacy of tolpyralate were evaluated in several sweet corn experiments from 2012 to 2016 in Western OR. Tolpyralate applied in 2012 to 6 corn varieties (including shrunken (SH2), sugar enhanced (SE), and sugary (SU) types), at 5 rates (from 0.018 to 0.071 lb ai/A), and with and without chlorpyrifos T-banded at planting, had no effect on corn color or growth. In 2013, tolpyralate was applied again at the same rates to the varieties Coho (SE), Captain (SU), Devotion (SH_2 white), and Owatonna (SH2 yellow) at the V4 growth stage and again no differences were noted in phyto after application or crop height at tasseling. In 2014, common purslane control with tolpyralate at 0.026 lb ai/A without atrazine but with MSO and UAN was 88%. In contrast, mesotrione at 0.094 ai/A plus COC and UAN had no effect on common purslane. In 2015, treatments with tolpyralate at 0.026 lb ai/A without atrazine applied to sweet corn (var. Mint, SH2) yielded as much or more than treatments of tembotrione, topramezone, and mesotrione. The most recent trial was placed in a grower's field in 2016, and weed control with tolpyralate at 0.026 lb ai/A when applied without atrazine was significantly better than tembotrione, topramezone, bicyclopyrone, and mesotrione.

Response of Walnuts to Simulated Drift Rates of Bispyribac-Sodium, Bensulfuron and Propanil. Mariano F. Galla*, Kassim Al-Khatib, Bradley D. Hanson; UC Davis, Davis, CA (099)

English walnut is one of the top commodities grown in California and its importance has been increasing in the last decade, with a gross dollar value of about $980 million in 2015. In the Sacramento Valley, walnut orchards are often in close proximity to rice fields. The majority of rice herbicides are applied by aircraft between May and July, that coincides with a period of rapid growth for walnut trees and flower bud initiation for the subsequent year's crop. Therefore, rice herbicide drift has the potential to impact walnut trees in the year of exposure and also nut yield in the subsequent year. An experiment was established at the UC Davis research station to study symptoms, injury, and growth of walnut after exposure to simulated drift of several herbicides commonly used in rice production. Bispyribac-sodium, bensulfuron and propanil were applied at four rates representing 0.5%, 1%, 3% and 10% of the normal use rate in rice. Data collection included injury ratings, observations of symptomology, number of internodes and nut yield. Bispyribac appeared to be more active than bensulfuron when applied at rates lower than 3% of the rice use rate. At higher rates, however, bensulfuron had more activity. Propanil caused significant damage only when applied at 10% of the use rate. These results indicate that bispyribac-sodium has the potential to cause symptoms and slow growth in walnuts more than other herbicides. However, the trees appeared to recover during the growing season and, thus far, no yield reductions have been observed.

Mesotrione: an Effective Herbicide for Use in Tree Nuts. Joshua I. Adkins*[1], Ryan S. Bounds[2], Dane Bowers[3], Derrick L. Hammons[4], Monika Saini[3]; [1]Syngenta, Richland, WA, [2]Syngenta, Visalia, CA, [3]Syngenta, Greensboro, NC, [4]Syngenta, Arbuckle, CA (100)

Broadworks™ is a herbicide from Syngenta that was registered in 2015 for weed control in tree nuts. The product contains the active ingredient mesotrione. The mode of action is through competitive inhibition of the HPPD (4-hydroxyphenyl-pyruvate dioxygenase) enzyme (group 27). Tree nut crops included on the label are almond, hazelnut, pecan, pistachio, black walnut, and English walnut. Trees must be established for a minimum of 12 months prior to application. Broadworks may be mixed and applied in combination with most commonly used herbicides registered for use in the approved crops in order to expand the postemergence or residual weed control spectrum.

Oxyfluorfen + Penoxsulam for Preemergence and Postemergence Weed Control in Stone, Pome, Olive, and Pomegranate Trees. Joe Armstrong*[1], Alistair H. McKay[2], Harvey A. Yoshida[3], James P. Mueller[4], Byron B. Sleugh[5], Richard K. Mann[5]; [1]Dow AgroSciences, Fresno, CA, [2]Dow AgroSciences, Clovis, CA, [3]Dow AgroSciences, Richland, WA, [4]Dow AgroSciences, Clayton, CA, [5]Dow AgroSciences, Indianapolis, IN (101)

Pindar® GT herbicide combines two effective active ingredients from two modes of action, oxyfluorfen + penoxsulam, into a single product for use in tree nut and fruit orchards. Oxyfluorfen is a protoporphyrinogen oxidase (PPO) inhibitor (WSSA Group 14) and penoxsulam is an acetolactase synthesis (ALS) inhibitor (WSSA Group 2). Pindar GT provides broad-spectrum burndown and residual control of over 50 broadleaf weeds and is registered for use in tree nuts (almond, walnut, pecan, and pistachio). In 2016, the label was expanded to include dormant season applications in stone, pome, olive, and pomegranate trees. Pindar GT can be used at rates of 1.5-3.0 pints/acre (850-1700 g ai/ha) on stone and pome trees that are at least four years old and olive and pomegranate trees that are at least two years old. In 33 efficacy trials conducted from 2012-2016 in the western United States, Pindar GT at 3 pints/acre (1700 g ai/ha) provided ≥ 94% residual control of several key weeds, including mallow (*Malva* spp.), hairy fleabane (*Conyza bonariensis*), and annual sowthistle (*Sonchus oleraceus*), for up to six months after dormant season application. In comparison, indaziflam (51 g ai/ha) provided 53-100% control and flumioxazin (430 g ai/ha) provided 45-99% control across the same weed spectrum. Pindar GT may also be tank-mixed with other herbicides to incorporate additional modes of action and/or broaden the spectrum of weed control.

Multiple Years of Evaluating Amicarbazone and Methiozolin for *Poa annua* Control in Turf.
Kai Umeda*; University of Arizona, Phoenix, AZ (102)

Methiozolin at 0.5 lb a.i./A was applied sequentially four times at 10-14 day intervals to compare timing of applications in the fall beginning in September versus October. Amicarbazone at 0.02 and 0.04 lb a.i./A and bispyribac-sodium at 0.01 lb a.i./A were applied sequentially 6 times at 10-14 days to evaluate and determine *Poa annua* control efficacy beginning in the fall of 2013 to the present. In December 2013 at 1 month after the final applications were made, methiozolin caused up to 75% *P. annua* injury, bispyribac-sodium caused 53% injury, and amicarbazone showed no evidence of injury. In the spring 2014, methiozolin applied beginning in October exhibited nearly acceptable control of *P. annua* at 83% while the early timing initiated in September was similar to amicarbazone and bispyribac-sodium at 36 to 58% control. The same treatments were re-applied in fall 2014, spring and fall 2015, and fall 2016. Methiozolin applications initiated in October consistently showed improved *P. annua* control at acceptable levels better than 80% compared to September initiation. Amicarbazone at 0.04 lb a.i./A performed better than the lower rate against *P. annua*. Amicarbazone caused phytotoxicity on the creeping bentgrass golf green while methiozolin and bispyribac-sodium caused slight discoloration of the turf.

Control of Broadleaf Weeds with Two New Formulations of Halauxifen-methyl (GF-3566 and GF-2687) in Cool and Warm Season Turfgrass. Vanelle F. Peterson*[1], Jamie M. Breuninger[2], Anita L. Alexander[3], Daniel D. Loughner[4]; [1]Dow AgroSciences, Fort Collins, CO, [2]Dow AgroSciences, Indianapolis, IN, [3]Dow AgroSciences, Lawrenceville, GA, [4]Dow AgroSciences, Lawrenceville, NJ (103)

GF-3566 is a systemic, postemergent herbicide composed of three proprietary active ingredients from Dow AgroSciences LLC for use on turfgrass. Two of the three active ingredients (halauxifen-methyl (Arylex™) and 2,4-D choline) are new to the turf market and the third component is fluroxypyr. The three actives are synthetic auxin herbicides which act through a synthetic auxin mechanism (HRAC group O, WSSA group 4) mode of action.

GF-3566 provides quick activity and control of key problem weeds in cool season and bermudagrass turf. Upon US EPA registration, GF-3566 is expected to have a signal word of "Warning" rather than the "Danger" signal word attributed to many of the 2,4-D amine containing products. The application rates will vary from 3.5 - 4.67 L/ha (3.5 - 4.0 pints/A) with use rates based on weeds and turfgrass species present. Positive attributes of GF-3566 include low odor and low volatility. GF-3566 is compatible with both low volume and traditional turfgrass application equipment, and mixes well in the tank with fertilizer and other products.

GF-2687 is also a systemic postemergent herbicide that controls both annual and perennial broadleaf weeds within southern turf stands. GF-2687 is a 1:1 ratio of Arylex plus florasulam (HRAC group B, WSSA group 2) combining two distinct modes of action to help avoid and delay weed resistance. The application rate of GF-2687 is 50 g/ha (0.72 oz/A) and applications are rain fast after one hour. This low use rate provides effective weed control and is non-injurious across major warm and cool season turfgrass species. Turfgrass tolerance, even on herbicide sensitive St. Augustinegrass, has been demonstrated at temperatures above 32° C (90°F). Upon US EPA registration, GF-2687 is expected to have a Caution signal word with no buffer zone or temperature restrictions. Coupling these features with one rate, safety across numerous turfgrass species, and effective performance on targeted weeds, GF-2687 will deliver maximum application flexibility for turfgrass managers.

Tree studies have shown that GF-3566 and GF-2687 can be used under tree drip lines without concern for off-target or root uptake injury. Upon registration the expected use sites will include established turfgrass (commercial and residential), commercial sod farms, ornamental and sports turf, golf course fairways, aprons, roughs and tee boxes, campgrounds, parks, recreation areas, cemeteries, and unimproved turfgrass areas.

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Sub-Lethal Glyphosate and Dicamba Doses in Dry Bean, Field Pea, and Potato. Harlene M. Hatterman-Valenti*[1], Michael Ostlie[2], Gregory Endres[2], Brian Jenks[3], Richard Zollinger[1], Andrew Robinson[1]; [1]North Dakota State University, Fargo, ND, [2]North Dakota State University, Carrington, ND, [3]North Dakota State University, Minot, ND (104

Herbicide spray drift is the most common complaint in relation to pesticide use in North Dakota. With the development of glyphosate-resistant crops and the quick conversion to these cropping systems, glyphosate was often the herbicide suspected for off-target injury. However, dicamba-resistant soybean and the adoption of this technology to combat glyphosate-resistant weed problems, may cause even more drift injury to off-target horticultural crops. Dicamba is known to be volatile and can remain in spray equipment if not cleaned properly, which may injure off-target plants during spraying operations. An overview of six simulated drift studies using glyphosate, dicamba, and mixtures of both herbicides on field pea *(Pisum sativum* subsp. arvense L.), dry bean (*Phaseolus vulgaris* L.), and potato (*Solanum tuberosum* L.) will be presented. All studies used three sub-lethal doses at 10-fold increments of glyphosate and dicamba, along with high, medium, and low doses of both herbicides mixed together. The highest dose for each herbicide did vary for the three crops due to sensitivity differences. Herbicide doses were targeted for the R1 stage with field pea and dry bean, and at tuber initiation for potato. Visual injury observations were made 10 and 20 days after treatment (DAT), while yields and grades were collected at the end of the growing season. For field pea, visual injury was relatively low ≤ 21% at 10 DAT and decreased by 20 DAT. Visual injury symptoms were greater for dry bean, especially when doses included dicamba. For potato, visual injury was greatest for doses that included dicamba, but were relatively low ≤ 13% at 10 DAT and increased two-fold or more by 20 DAT. Yield reduction compared to the untreated was greatest when doses included dicamba, regardless of the crop. Results suggest that drift injury potential to field pea, dry bean, and potato will be greater if a dicamba-resistant soybean crop is adjacent and upwind compared to a glyphosate-resistant crop.

Herbicide Testing in Field-Grown Ornamentals. Timothy W. Miller*, Carl R. Libbey; Washington State University, Mount Vernon, WA (105)

A number of ornamental crops were tested for sensitivity to several herbicides in trials conducted near Mount Vernon, Washington in 2015 and 2016. One-year-old peony was treated with 3 rates each of dithiopyr, dimetheamid-p, isoxaben, or indaziflam (granular and liquid formulations), as well as prepackaged mixes of dimethenamid-p + pendimethalin (granular), and sulfentrazone + prodiamine (liquid) in 2015 and again in 2016. Applications were made at 2 timings: immediately postemergence (mid-March) and again 6 weeks later (late April) in both years. Peony growth and flower bud production was severely reduced by dithiopyr at tested rates, ranging from 28 to 57% by late April, 2016. In a separate peony trial in 2016, napropamide, dithiopyr, sulfentrazone + prodiamine, isoxaben, indaziflam, pendimethalin, s-metolachlor, oryzalin, mesotrione, and dimethenamid-p applied in late January, 2016 did not cause peony foliar injury, and number of flower buds did not differ among treatments. Tulip, daffodil, and iris, bulbs transplanted in October were treated with mesotrione, dithiopyr, dimethenamid-p, bicyclopyrone, and indaziflam in November, 2015. Indaziflam caused 53% foliar injury to tulip and 25% foliar injury to daffodil by May, 2016, while foliar injury from the other herbicides ranged from 0 to 11%. Weed control from most treatments at that evaluation was excellent. Mesotrione and dithiopyr combination treatments were particularly effective, although dithiopyr and dimethenamid-p alone at the low rates still provided 95 to 98% control. Weed control with mesotrione and bicyclopyrone ranged from 60 to 80%, contrasted with 48% control from glyphosate alone. Tulip and daffodil stem length, and tulip flower number were all significantly reduced by indaziflam compared to glyphosate-only check. Mesotrione + isoxaben and dimethenamid-p also caused injury to flowers of more than one species. Except for the above-listed treatments, stem lengths resulting from treatments in this trial did not result in non-marketable flowers. In other trials, crocus, hyacinth, tulip, daffodil, and iris growth was not negatively affected by two applications of indaziflam at 4 different rates, although foliar senescence was more advanced in tulip and daffodil at the higher rates. Similarly, galdiola and dahlia were not injured by indaziflam at tested rates.

PROJECT 3: WEEDS OF AGRONOMIC CROPS

Investigation of Nozzle Erosion from Spray Mixtures using Commercial Application Equipment, Year One of a Multi-Year Approach. Raymond L. Pigati*[1], Andrea C. Clark[2], Lillian C. Magidow[3], Gregory K. Dahl[4], Eric P. Spandl[1], Joe V. Gednalske[2]; [1]Winfield United, Shoreview, MN, [2]Winfield United, River Falls, WI, [3]Winfield, River Falls, WI, [4]Winfield Solutions LLC, St. Paul, MN (075)

The implications of multiple spray applications over the course of a typical year with commercial application equipment to nozzle performance and the impact on nozzle orifice degradation is not well understood. A multi-year study using a commercial sprayer to determine the effects of spray applications on nozzles is being conducted. A sprayer was outfitted with TeeJet® AIXR11005 spray nozzles at the start of the spraying season and removed at the conclusion of the season. To quantify the impact after a full season of spray applications: flow rate, nozzle orifice size and droplet size were measured prior to and at the conclusion of the season. Results after the first year of the study have already shown changes in all three metrics. This current study will be continued for another year, wherein, some nozzles will be replaced with new TeeJet® AIXR 11005 nozzles and some nozzles will not be changed to determine the effects of two years' worth of spray applications.

Application of PPO Inhibitors to Dormant Mint Grown in Western Oregon. Kyle C. Roerig*, Andrew G. Hulting, Daniel W. Curtis, Carol Mallory-Smith; Oregon State University, Corvallis, OR (076)

Inhibitors of protoporphyrinogen oxidase (PPO) including carfentrazone, flumioxazin, and saflufenacil have been successfully utilized in a number of perennial crops to control small annual weeds. Small, emerged weeds are often controlled with paraquat in dormant, established mint. Trials here were conducted over three years to evaluate possible candidates to replace paraquat for this use pattern. Carfentrazone was applied at 0.0175 kg ai/ha. Flumioxazin rates were 0.072 to 0.143 kg ai/ha. Saflufenacil was applied at rates ranging from 0.025 to 0.05 lb ai/a. These herbicides were applied over a range of timings from dormant mint in January to mint with 12 cm of regrowth in April. April applications of all three herbicides caused a significant reduction in oil yield in 2016 compared to the highest yielding treatment. No other treatments reduced yield (p-value 0.05), including April treatments in other years. However, it is important note that due to highly variable yield data in some years a lack of significance in yield reduction does not necessarily equate to crop safety. Saflufenacil and flumioxazin controlled 99% or more of sharppoint fluvellin (*Kickxia elatine* (L.) Dumort.). Common groundsel (*Senicio vulgaris* L.) control of 97% or greater was achieved with saflufenacil, while carfentrazone and flumioxazin provided poor control of this species. Flumioxazin controlled 99% of purslane speedwell (*Veronica* peregrine L.), while control of this species was 78% with carfentrazone in February and less than 50% with saflufenacil. In 2014, April application of pyroxasulfone alone resulted in 38 and 25% control of red sorrel (*Rumex acetosella* L.) and sowthistle (*Sonchus asper* (L.) Hill), respectively. With the addition of saflufenacil, 100% control of both species was achieved. These results indicate that PPO inhibitor herbicides can be safely used in mint, but that attention to matching the correct herbicide to the weed spectrum present will be important for maximum efficacy.

Utility of the POST Soybean/Dry Bean Multi-Herbicide Sequential Application Program. Rich Zollinger*; North Dakota State University, Fargo, ND (077)

The micro-rate program was originally developed in sugarbeet by combining five registered sugarbeet herbicides, reducing the rate of each herbicide by 66 to 75% of the labeled rate, adding MSO adjuvant, and applying this tank-mixture three to five times every five to seven days until lay-by. A sequential tank-mix program was developed in North Dakota for use in soybean and drybean except herbicides rates were reduced 25 to 50% and treatments were applied once or twice. A tank-mix composed of three to four herbicides applied sequentially may improve weed control over current programs. The program includes bentazon at 5 oz/A plus sethoxydim at 1 oz/A plus imazamox at 0.125 oz/A plus fomesafen at 1 oz/A plus clethodim at 0.5 oz/A plus MSO adjuvant at 1.25 pt/A. This program was applied to a broad-spectrum of grass and broadleaf weeds at 1 to 3 inches tall (A), 2 to 4 inches tall (B), and 3 to 6 inches tall (C). Treatments were applied to green and yellow foxtail, wild mustard, redroot pigweed, common lambsquarters, hairy nightshade, kochia, wild buckwheat, common ragweed, and common cocklebur. A second application was made after the first application when weed regrowth or new weed flushes reached 1 to 3 inches tall. Another set of treatments was applied except fomesafen was replaced with cloransulam at 0.084 oz/A to test if cloransulam would increase control of large-seeded broadleaf weeds like common ragweed and common cocklebur. The treatments with fomesafen and cloransulam were applied at 8.5 and 17 gpa as preliminary research showed improved weed control from increasing spray volume (increase spray volume by 8 to 10 gpa for every 3 inches of weed height). Weed control was 99% 14 days after A and B applications (DAA) and 60 to 99% weed control from C application treatments. Ample rain after application caused new flushes of weeds in all plots. By 28 days after the first micro-rate application composite weed control from A, B, and C treatments was less than 50%, 60%, and 65%, respectively. However, 28 days after the second sequential applications (canopy closure) weed control in A, B, and C plots was 98%, 78%, and 68%, respectively. Replacing fomesafen with cloransulam resulted in less common ragweed control but composite weed control was similar to control from treatments with fomesafen. Applying treatments at 17 gpa compared to 8.5 gpa generally resulted in a 10 percentage point increase in weed control but an increase of 30 percentage points was observed in some treatments. Application of this multi-herbicide, multi-application program to small weeds in soybean provided excellent season-long control of a wide spectrum of weeds.

Confirmation and Management of Glyphosate-Resistant Russian Thistle (*Salsola tragus* L.) from Montana and Washington. Vipan Kumar*[1], Prashant Jha[2], John F. Spring[3], Anjani J[1], Drew Lyon[3], Ian C. Burke[3]; [1]Montana State University, Huntley, MT, [2]Montana State Universityn, Huntley, MT, [3]Washington State University, Pullman, WA (078

Occurrence of glyphosate-resistant (GR) weeds are an increasing management concern for growers in the no-till cereal-based production systems of the northwestern United States. During summer/fall of 2015, Russian thistle control failures with glyphosate were reported from chemical fallow fields in Choteau County, MT (MT-R) and Columbia County, Washington (WA-R). To confirm and characterize the levels of resistance in these GR populations relative to known glyphosate-susceptible (GS) populations (MT-S and WA-S from MT and WA, respectively), whole-plant glyphosate dose-response and shikimate accumulation assays were conducted. To understand the mechanism of resistance, the *EPSPS* (5-enolpyruvylshikimate-3-phosphate synthase) gene was analyzed for target-site mutations (PCR and sequencing) and increase in gene copy numbers (qPCR assay). On the basis of shoot dry weight response (GR_{50} values), the MT-R population showed 4.5-fold and 5.9-fold resistance to glyphosate relative to the MT-S population under greenhouse and outdoor conditions, respectively. The WA-R population had 3.0- to 5.0-fold resistance relative to the WA-S accession in greenhouse experiments, and 1.9- to 7.5-fold resistance in multi-site field experiments. The MT-S population accumulated approximately 4- and 9-times more shikimate than the MT-R and WA-R populations, respectively, 10 d after treatment with 1260 g ae ha^{-1} of glyphosate. Partial sequencing of the *EPSPS* gene revealed no mutations at the Thr102 or Pro106 codon in those GR populations. Additionally, no difference in the *EPSPS* genomic copy number was observed between GR and GS populations. Further investigations on transcript expression of the *EPSPS* gene and [14^{C}]-glyphosate uptake and translocation of GR vs. GS populations are under progress. This is the first global report on field-evolved GR Russian thistle identified in Montana and Washington. Growers should adopt diversified weed control tools including alternative, effective sites-of-action herbicides to prevent further spread of GR or evolution of multiple HR Russian thistle populations in this region.

Preplant Burndown Herbicide Options for Kochia Control in Sugarbeet. Andrew R. Kniss*, Gustavo Sbatella; University of Wyoming, Laramie, WY (079)

Glyphosate provides the basis of weed control programs in glyphosate-resistant sugarbeet. Shortly after glyphosate-resistant sugarbeet was widely adopted in the US, reduced tillage practices have become common. Reduced tillage practices like strip-till eliminate or reduce the ability to use pre-plant tillage to control early emerging weeds like kochia and common lambsquarters. If weeds are present at the time of sugarbeet planting, they must be controlled with herbicides. Glyphosate is still the primary means of controlling these weeds at the time of planting. The objective of this study was to evaluate other herbicides for preplant burndown of kochia to reduce selection pressure for glyphosate-resistance. Field studies were conducted at Research and Extension Centers near Lingle and Powell, Wyoming, in 2016. No sugarbeet injury was present in any plot at either location. Pyraflufen-ethyl applied without other herbicides provided less than 80% kochia control at Lingle, and up to 91% kochia control at Powell. Paraquat applied alone or in combination with pyraflufen-ethyl provided the most consistent kochia control among treatments evaluated. Adding pyraflufen to either glyphosate or glufosinate improved kochia control compared to either herbicide applied alone. Where pyraflufen-ethyl was applied, crop oil concentrate resulted in better kochia control compared to non-ionic surfactant in most cases. Mixtures of either pyraflufen-ethyl plus glufosinate or pyraflufen-ethyl plus paraquat provided excellent kochia burndown and could

be an effective (albeit more costly) replacement for glyphosate before sugarbeet planting to reduce selection pressure for glyphosate-resistant weeds.

Impact of Management Systems and Predicted Climate Scenarios on Weed Communities. Tim Seipel, Suzanne Ishaq, Fabian Menalled*; Montana State University, Bozeman, MT (080)

Crop yield is influenced by agricultural practices as well as biological and environmental stressors. We compared winter wheat yields and weed communities across three framing systems and contrasting climate conditions at the Fort Ellis Research Farm near Bozeman, MT. Farming systems included a conventional no-till system that relies on chemical inputs for nutrient and weed management (conventional), an organic farming system reliant on tillage for weed control and cover crop termination (tilled-organic), and an organic system that uses sheep grazing to control weeds and terminate cover crops (grazed-organic). Environmental treatments included ambient climate condition, a hotter climate condition that was created using open-top chambers that increased temperatures ~2C, and a hotter and drier climate condition that was achieved using open-top chambers and rain-out shelters that block approximately 50% of precipitation. We modeled the response variables using generalized linear mixed-effects models, and used ANOVA and post-hoc Tukey tests to determine if farming systems and climate conditions caused variation in yields. Multivariate analysis was used to compare weed communities across cropping systems and climate conditions.

Under ambient conditions, winter wheat yield varied by farming system with yields similar between the conventional (5.7 t/ha) and tilled-organic systems (5.1 t/ha; $P=0.37$), and lowest in the grazed-organic system (3.1 t/ha; $P<0.001$). Wheat yield in the hotter and drier climate condition declined 46% ($P=0.02$) when compared to the ambient conditions in the conventional farming system. In contrast, wheat yield in the tilled-organic system and the grazed-organic system remained at 99% and 89% relative to ambient under the hotter and drier conditions ($P=0.17$ and $P=0.14$, respectively). Weed biomass and number of weed species were highest in the grazed-organic system (14.4 g and 4.4 species per plot; $P=0.08$ and $P=0.03$, respectively), and lowest in the conventional farming system (0.60 g and 0.4 species per plot) and the tilled-organic system (3.8 g and 1.5 species per plot). Climate did not influence the number of weed species ($P=0.96$) or weed biomass ($P=0.87$) but impacted individual species seed production. Weed community composition varied in response to farming system ($P=0.001$, $R^2=0.28$), but not in response to climate conditions ($P=0.77$, $R^2=0.02$). Overall, our initial results indicated that there could be more resilience within organic systems to increased temperatures and lower moisture, and *B. tectorum* could be a better competitor against winter wheat under hotter and drier climate conditions.

Introduction of StrikeLock; a Novel Adjuvant System. Ryan J. Edwards*[1], Gregory K. Dahl[2], JoAnna A. Gillilan[3], Raymond L. Pigati[4], Andrea C. Clark[5], Eric P. Spandl[4], Joe V. Gednalske[5]; [1]Winfield United, River falls, WI, [2]Winfield Solutions LLC, St. Paul, MN, [3]Winfield

United, Springfield, TN, [4]Winfield United, Shoreview, MN, [5]Winfield United, River Falls, WI (081)

The performance of certain herbicides is increased with the use of oil based adjuvants. However, oil adjuvants are not recommended for use with glyphosate, due to proven antagonism. Methylated Seed Oil-High Surfactant Oil Concentrates (MSO-HSOC) are a newer generation of oil based adjuvants. MSO-HSOC (e.g. Destiny® HC and Superb® HC) are classified as containing 25-50% w/w surfactant with a minimum of 50% w/w oil. MSO-HSOC have shown excellent compatibility with glyphosate while providing equivalent performance as other oils. StrikeLock™ is a new, novel MSO-HSOC adjuvant that provides optimal weed efficacy similar too other MSO-HSOC adjuvants with the included benefit of increased drift and deposition properties. Drift performance testing of StrikeLock™showed a decrease in fine production comparable to other commercial drift reduction agents. Field trials were also conducted across the United States on multiple crops and weeds to determine performance of many hydrophobic herbicides. In all field trials, StrikeLock™ provided similar to better weed efficacy as compared too similar MSO-HSOC adjuvants.

Viability Assessment of Mutagenesis-derived ACCase Resistant Wheat Lines as a New System for Control of Winter Annual Grasses. Curtis M. Hildebrandt*, Scott Haley, Phil Westra, Todd Gaines; Colorado State University, Fort Collins, CO (082)

In wheat cropping systems, competition with winter annual grass species such as *Aegilops cylindrica* Host, *Bromus tectorum* L., and *Secale cereale* L. can negatively impact yield. A novel resistance trait for the ACCase inhibitor quizalofop p-ethyl was integrated into advanced wheat breeding lines. During the 2015-2016 growing season, herbicide efficacy and field crop safety trials were performed to assess crop safety on a two-gene (A and D genome) wheat line and weed control efficacy for the three winter annual grasses. Quizalofop rates from 30.8 g ai ha^{-1} up to 185 g ai ha^{-1} with 1% MSO were applied in autumn and spring, and injury evaluations were taken 3 weeks after spring application. Weed control efficacy trials were performed by planting quizalofop-resistant wheat with the three grass weed species in the autumn. In the spring, ten treatments were applied at the tillering growth stage of the three weed species: 30.8, 46.3, 61.7, 77.1, and 92.5 g ai ha^{-1} all with NIS at 0.25%; 61.7 g ai $ha^{-1}$with 1% MSO; 61.7 g ai ha^{-1} with 1% COC; 61.7 g ai ha^{-1} with 1% NIS; and 61.7 g ai ha^{-1} with 0.25% NIS and 28 L ha^{-1} of UAN 32%. Neither autumn nor spring treatments resulted in detectable injury on the two-gene wheat lines, indicating high levels of crop safety. Greater than 90% control was observed for all three weed species tested within rates deemed safe for use on the 2-gene wheat.

Commercial Launch of a New Herbicide Tolerant Wheat Production System. Chad Shelton*; Albaugh, Anky, IA (083)

Three major agricultural organizations have established a strategic collaboration towards innovative and novel solutions for wheat producers. The partnership targets the development and distribution of wheat varieties with a non-GMO trait conferring tolerance to a new herbicide for wheat to control winter annual grasses. The collaborating partners include, Colorado Wheat Research Foundation, Inc. (CWRF), Albaugh LLC, global leader for post-patent agri-chemicals and Limagrain a farmer-owned international seed group. This unique three-way partnership will deploy the use of this technology exclusively on a worldwide basis. This innovative technology will help deliver new grass and broadleaf control to farmers across the North American cereal market and around the globe.

In 2018 the partnership will launch a new cereal production system that is driven by a patented trait and a new herbicide (Albaugh 2017) for control of tough winter annual grasses in winter wheat. The launch of this new herbicide tolerant wheat production system will combine public and private trait introgression into elite germplasm and combined with a robust stewardship program for all classes of winter wheat grown in the US market. The successful commercial launch of this new cereal production system will be driven by innovation, performance and grower value.

Plant Back of Russet Burbank Seed Treated with Glyphosate and Dicamba. Nelson Geary*, Harlene M. Hatterman-Valenti, Andrew Robinson; North Dakota State University, Fargo, ND (084)

The introduction of dicamba-tolerant soybean will allow dicamba treatments through the R1 soybean growth stage; however, it is unknown how the contamination of dicamba and glyphosate residues in seed potato will affect emergence and production. Our objective was to determine the effects of planting back seed that was exposed to dicamba and glyphosate the previous year. Trials were conducted at Oakes and Inkster, North Dakota in 2016. Dicamba and glyphosate were applied during tuber initiation at sub-lethal doses to simulate drift in 2015. Tubers from 2015 progeny were harvested and stored until being planted as seed in 2016. Stand and stem counts were taken at 8 weeks after planting. Tubers were harvested and evaluated at the end of the growing season. As glyphosate and/or dicamba dose increased on the mother plant, yield from seed planted back decreased. The treatment of 99 g ai/ha dicamba plus 197 g ae/ha glyphosate in 2015 caused 15% yield loss at Oakes, and 5% yield loss at Inkster, ND. When the seed was planted back in 2016 that received 99 g ai/ha dicamba plus 197 g ae/ha glyphosate in 2015, stand was reduced by 25% and yield loss was 33% at Oakes. When the same treatment was planted back at Inkster, the stand was reduced by 89% and yield loss was 68%. Total yield reductions, when glyphosate and dicamba were applied to mother plants, were attributed to fewer tubers from nonemerging plants. Precautions should be taken to avoid glyphosate and dicamba contamination of seed tubers.

Fall Preemergence Herbicide Applications to Spring Plantings of Cool Season Grass Seed Crops. Daniel W. Curtis*, Kyle C. Roerig, Andrew G. Hulting, Carol Mallory-Smith; Oregon State University, Corvallis, OR (085

Oregon's grass seed production is dependent on the ability to produce weed free seed. Annual bluegrass (*Poa annua*) and roughtalk bluegrass (*Poa trivialis*) are two weed species which pose contamination threats to seed production. For the production of tall fescue and the fine fescues, predominately chewings and creeping red, spring planting is the most cost effective method of crop establishment. A major problem growers face is that potential herbicides for fall preemergence use in these spring planted stands, including flufenacet/metribuzin, s-metolachlor, dimethenamid-p, diuron and metribuzin, state that they can only be applied following the first seed harvest or to established crops at least one-year old. The exception is pendimethalin, which needs water incorporation, and most of these plantings are non-irrigated.

Five studies conducted at the Oregon State University research farm in Corvallis evaluated fall herbicide applications to spring planted fescue stands. The grasses were planted in the spring, either April or May, and allowed to go dormant through the low rainfall months of July, August and September. In 2010-11, pyroxasulfone/flumioxazin and flufenacet/metribuzin were compared to an untreated check treatment. The herbicide treatments controlled the annual bluegrass at 90% or greater, and yields were not reduced. In 2012-13, a study compared several herbicides including flufenacet/metribuzin plus diuron, indaziflam, pyroxasulfone, pyroxasulfone/flumioxazin, terbacil plus diuron and metribuzin. The flufenacet/metribuzin, indaziflam and pyroxasulfone/flumioxazin controlled roughstalk bluegrass 93% or greater, and flufenacet/metribuzin, indaziflam, pyroxasulfone/flumioxazin and pyroxasulfone controlled annual bluegrass 92% or greater. No control of the weeds occurred with the terbacil plus diuron treatment or metribuzin. Yields were equivalent in all treatments. In 2015, four herbicide treatments were applied to a spring planting of tall fescue at three timings in the fall. Flufenacet/metribuzin, pyroxasulfone/flumioxazin, EPTC and indaziflam were applied nine days prior to the first fall rain event of 0.23 inches, one day prior to the rain event and 29 days following the rain event. The herbicide treatments with the exception of the EPTC controlled annual and roughstalk bluegrass 93% or greater. None of the treatments reduced yield. Two studies investigated fall applications of herbicide treatments to spring plantings of creeping red fescue and chewings fescue in 2015. Treatments included flufenacet/metribuzin, indaziflam, pyroxasulfone/flumioxazin, dimethenamid-P, A20540B and s-metolachlor. In the creeping red fescue study, flufenacet/metribuzin, indaziflam, and pyroxasulfone/flumioxazin controlled both roughstalk and diuron resistant annual bluegrass 94% or greater and no treatments reduced yields. In the chewings fescue study, flufenacet/metribuzin, indaziflam, pyroxasulfone/flumioxazin and dimethenamid-P controlled roughstalk bluegrass and diuron resistant annual bluegrass 90% or greater. All treatments except indaziflam reduced yield in comparison to the untreated. No injury was observed in the chewings fescue and yield reductions might be mitigated with rate reductions. In these five studies, diuron resistant annual bluegrass was controlled at levels 90% or greater with the fall applications and in the four studies with roughstalk bluegrass, the fall applications with flufenacet/metribuzin, pyroxasulfone/flumioxazin and indaziflam controlled 93% or greater of the roughstalk bluegrass. In general, fall applications of flufenacet/metribuzin, pyroxasulfone/flumioxazin and indaziflam to spring planted grass seed were effective and safe.

Cytochrome P450 Modulates 2,4-D Metabolic Resistance in Waterhemp (*Amaranthus tuberculatus*). Marcelo R. de Figueiredo*[1], Darci A. Giacomini[2], Patrick Tranel[3], Phil Westra[1], Franck Dayan[1], Scott Nissen[1], Todd Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]University of Illinois, Champaign, IL, [3]University of Illinois at Urbana–Champaign, Champaign, IL (086)

The mechanisms of resistance in weeds to synthetic auxin herbicides are poorly understood. About five years ago, a population of waterhemp was characterized as resistant to 2,4-D in the state of Nebraska, but the physiological, biochemical and genetic changes that cause the resistance are still unknown. To understand these mechanisms, we studied the physiological basis of 2,4-D resistance including herbicide translocation, absorption and metabolism. We did not find differences in absorption between the resistant (R) and susceptible (S) populations, however, we observed that the herbicide translocation in the R population was 1.5 times higher than in the S. In our metabolic analysis, we found that the herbicide was metabolized rapidly forming six different compounds in the R population, while just one main metabolite was found in the S population. To analyze the enzymatic machinery regulating the herbicide detoxification, we applied a cytochrome P450 inhibitor, which restored sensitivity to 2,4-D in the R population and reduced the rate of 2,4-D metabolite formation. An improved understanding of the molecular and biochemical bases of auxinic herbicide metabolism in plants is important for the sustainable use of these herbicides now and in the future when auxin-resistant crops will be introduced in the market.

Survival, Growth, and Reproductive Fitness of Dicamba-Resistant Kochia in the Presence of Dicamba. Charlemagne A. Lim*, Prashant Jha, Vipan Kumar, Shane Leland, Anjani J; Montana State University, Huntley, MT (127)

Field experiments were conducted at the MSU–SARC, Huntley, MT to determine survival, growth, and reproductive fitness of dicamba-resistant (DR) kochia with variable resistance to dicamba. Seeds from a segregating DR kochia population collected from a wheat field in MT were used. Susceptible (DS) and DR lines were obtained after three generations of recurrent selection. Experiments were conducted in a randomized complete block, factorial design, with six replications, and repeated. Kochia seedlings with known resistance to dicamba (DS, DR1 = 1.5-fold, DR2 = 2.5-fold, DR3 = 6.8 fold) were transplanted into the field. Plants (13-cm tall) were treated with dicamba at 0, 35, 70, 140, 280, 560, 840, 1120, 2240 g ha^{-1}. Doses needed to achieve 90% control (ED_{90}) were 1,601 and 1,937 g ha^{-1} for DR1 and DR2, respectively, compared to 3,884 g ha^{-1} for the highly-resistant DR3 kochia. The ED_{90} values for seed reduction ranged from 1,545 to 4,202 g ha^{-1} for DR lines compared to 227 g ha^{-1} for the DS line. Dicamba applied at the highest rate reduced fecundity of DR1 line by 270-fold (108,000 to 400 seeds $plant^{-1}$). In the absence of dicamba, DR lines produced 24 to 53% less seeds compared to DS. Although no differences in pollen viability and seed viability, DS kochia took less days to reach 50% flowering and seed set, and had higher 1000-seed weight compared to DR lines, averaged across dicamba doses. Results indicate a fitness cost in DR kochia in the presence or absence of dicamba.

Polyploidy and Herbicide Resistance in *Echinochloa colona* from California. Sarah Morran*[1], Bradley D. Hanson[2]; [1]The University of California, Davis, Davis, CA, [2]UC Davis, Davis, CA (128)

Junglerice (*Echinochloa colona*) is a C_4 annual weed with a broad geographical distribution in agricultural regions worldwide. In California specialty cropping systems such as vineyards and orchards, junglerice is present as a summer growing weed able to germinate throughout the season whenever favorable temperature and water conditions are present. Management of junglerice and other summer weeds relies heavily on the non-selective herbicide glyphosate. Recently, glyphosate resistant (GR) junglerice biotypes with a range of resistance levels have been identified across the Central Valley agricultural area. The possible mechanism(s) of resistance has been investigated and results show that altered absorption and/or translocation as well as metabolism are not contributing to resistance in any of the biotypes tested. A region of the 5-enolpyruvylshikimate-3-phosphate synthase (EPSPs) gene from each biotype has been sequenced to look for target site mutations (TSM) that may be conferring resistance in these plants. Single nucleotide changes at Proline 106 were identified in these resistant biotypes with resistance alleles showing high sequence similarity to the previously identified *EPSPS gene 1* in *E. colona*. Three different single nucleotide changes at Proline 106; Pro106Leu, Pro106Thr and Pro106Ser, were identified among the lines suggesting resistance has evolved independently multiple times in the orchards surveyed. The contribution of the detected TSM to the observed resistance in these hexaploid biotypes is being investigated further with the aim to characterize the expression of specific alleles and identify potential transcriptional bias between homoeologous genomes of junglerice in resistant and susceptible lines.

Dissipation of Soil-Applied Herbicides under Limited Irrigation. Daniel M. Adamson*[1], Gustavo Sbatella[1], Andrew R. Kniss[1], Franck Dayan[2]; [1]University of Wyoming, Laramie, WY, [2]Colorado State University, Fort Collins, CO (129)

Soil-applied herbicides are important for controlling weeds in many crops, as they offer a broadened control spectrum and chemical diversity, particularly when POST-applied herbicide options are limited. However, if soil-applied herbicides persist for an extended time, there is risk for damage to susceptible rotational crops in succeeding years. As herbicide degradation in the soil is dependent on water, among other factors, imminent needs to reduce agricultural water use in the future could lead to limited herbicide degradation and a greater risk for carryover in the next growing season. This project seeks to understand how limited irrigation affects dissipation of soil-applied herbicides in irrigated crop rotations. A field study was undertaken by applying 8 soil-applied herbicides to dry beans and corn. Three irrigation treatments (100, 85, and 70% of crop evapotranspiration) were applied with an overhead sprinkler. Volumetric water content of the soil was monitored using GS1 soil moisture sensors, showing volumetric water content of the three irrigation treatments averaged 22, 18 and 17% throughout the growing season in 2015, and 26, 23 and 20% in 2016. Soil samples taken 0, 1, 7, 14, 21, 28, 42, 56, 70, 84, 112, and 140 days after application were analyzed for herbicide level using gas or liquid chromatography and mass spectrometry. Results were regressed over time to produce a degradation curve and soil half-life estimate for each herbicide and irrigation treatment. Reduced irrigation never significantly increased soil half-life of any herbicide tested for both study years.

Florasulam plus Halauxifen-methyl Premix for Preseed Weed Control in Cereals plus Sequential Postemergence Herbicide Programs. Joseph P. Yenish*[1], Patricia Prasifka[2], Mike

Moechnig[3], Roger Gast[4]; [1]Dow AgroSciences, Billings, MT, [2]Dow AgroSciences, West Fargo, ND, [3]Dow AgroSciences, Toronto, SD, [4]Dow AgroSciences, Indianapolis, IN (130)

Quelex™ herbicide is a new broadleaf herbicide from Dow AgroSciences which is largely intended for foliar applications, but also provides short term residual activity. Quelex received federal registration for use in cereals July 2016. It is available as a water dispersible granule (WDG) containing 10% Arylex™ active (halauxifen-methyl) and 10% florasulam w/w. Arylex™ active is a new novel synthetic auxin (WSSA group 4) active ingredient from the new arylpicolinate chemical class being developed for the U.S. and many major cereal markets around the globe. Quelex is the first U.S. product containing Arylex active and has a use rate of 52.5 grams of product/ha (0.75 oz pr/acre) [Arylex (halauxifen-methyl 5.25 g ae/ha) + florasulam (5.25 gai/ha)]. Quelex is currently registered for post-emergence applications in wheat (including durum), barley and triticale. A U.S. label allowing for preplant and post-plant prior to cereal crop emergence burndown application is anticipated in late 2017. Once this label is approved Quelex will offer cereal producers a unique broadleaf weed control spectrum and favorable crop rotation flexibility with several options of application timings. Field research was conducted from the 2014 to 2016 cropping seasons at multiple locations across MT, ND, and SD to determine the efficacy and crop safety of Quelex applied in conjunction with glyphosate as a pre-seed burndown ahead of spring cereals. Weed control efficacy and crop response of Quelex + glyphosate was compared to glyphosate plus saflufenacil, dicamba or carfentrazone. Quelex demonstrated similar or greater control of weeds such as redroot pigweed (*Amaranthus retroflexus*), volunteer canola (*Brassica rapa*), common lambsquarters (*Chenopodium album*), narrow-leaf hawksbeard (*Crepis tectorum*), and wild buckwheat (*Polygonum convolvulus*) compared with glyphosate alone or the other commercial tank-mixes. Quelex + glyphosate also demonstrated good crop safety on spring wheat (including durum) and barley. Quelex herbicide with Arylex Active will provide cereal growers with an effective multi-mode-of-action herbicide option for many difficult to control broadleaf weeds in burndown applications.

Pyroxasulfone Root vs Foliar Uptake for Control of Grasses. Codee Z. Lee*, Kirk A. Howatt; North Dakota State University, Fargo, ND (131)

Pyroxasulfone is a very long chain fatty acid inhibitor labeled to control grasses and small-seeded broadleaf weeds. Little information is available regarding the use of this product as a postemergence herbicide. The objective of this study was to determine where pyroxasulfone uptake in the plant occurs, via foliage or roots. Two root vs foliar greenhouse studies were conducted in the winter of 2016-2017 as completely randomized designs (CRD) with four replicates. To evaluate foliar vs soil effects, foliar alone and soil alone applications were included, as well as a combined foliar and soil application for comparison. Pyroxasulfone at 119 and 238 g ha^{-1} at the two leaf stage was applied under each placement method. Previous greenhouse studies showed pyroxasulfone applied postemergence had greater than 90% control of green foxtail, downy brome, and Japanese brome. Pyroxasulfone viability on troublesome grasses led to further focus on its initial source of control. Pyroxasulfone at 119 and 238 g ha applied to soil alone and both soil and foliage gave similar control of downy brome, green foxtail, and wild oat, while foliage alone applications at both rates gave no control of these grass species. These studies demonstrated that pyroxasulfone activity is a result of root uptake.

Florasulam plus Halauxifen-methyl Premix Combined with Fluroxypyr plus Clopyralid for Improved In-crop Control of Broadleaf Weeds in Spring Cereals. Patricia Prasifka*[1], Michael Moechnig[2], Joseph P. Yenish[3], Roger Gast[4]; [1]Dow AgroSciences, West Fargo, ND, [2]Dow AgroSciences, Toronto, SD, [3]Dow AgroSciences, Billings, MT, [4]Dow AgroSciences, Indianapolis, IN (132)

Quelex™ herbicide, a new broadleaf herbicide from Dow AgroSciences, received federal registration July 2016 for post-emergence applications in wheat (including durum), barley and triticale. It is available as a water dispersible granule (WDG) containing 10% Arylex™ active (halauxifen-methyl) and 10% florasulam w/w. Arylex active is a new novel synthetic auxin (WSSA group 4) active ingredient from the new arylpicolinate chemical class being developed for the U.S. and many major cereal markets around the globe. Quelex is the first U.S. product containing Arylex active and has a use rate of 52.5 grams of product/ha (0.75 oz pr/acre) [Arylex active (halauxifen-methyl 5.25 g ae/ha) + florasulam (5.25 g ai/ha)]. Quelex has efficacy on small-seeded broadleaf weed species such as red-root pigweed (*Amaranthus retroflexus*), common lambsquarters (*Chenopodium album*), and mustard and mint species and consequently will be a complementary tank-mix partner with WideMatch® herbicide (fluroxypyr + clopyralid) which is particularly effective on kochia (*Kochia scoparia*) and Canada thistle (*Cirsium arvense*) among many other broadleaf weed species. Field research was conducted from 2014 to 2016 at multiple locations across MT, ND, and SD to determine the efficacy and crop safety of Quelex applied in conjunction with WideMatch as a post-emergence application in spring cereals. Weed control efficacy and crop response of Quelex plus WideMatch was compared to WideMatch alone as well as other competitive products and tank-mixes. The combination of Quelex plus WideMatch provided similar or greater control of weeds such as redroot pigweed (including suspected ALS-resistant populations), volunteer canola (*Brassica rapa*), common lambsquarters, kochia, and wild buckwheat (*Polygonum convolvulus*) compared with WideMatch alone or the other commercial products and tank-mixes. Quelex plus WideMatch also demonstrated excellent crop safety on spring wheat and barley. A Quelex plus WideMatch tank mix will provide an effective multi-mode-of-action treatment option for broad-spectrum control of common and difficult to control broadleaf weeds in northern U.S. cereal growing regions.

Soybean PRE Herbicide Effectiveness with Limited Water. Mike H. Ostlie*, Gregory Endres; North Dakota State University, Carrington, ND (133)

Many important soybean PRE herbicides rely on water to activate. These products are often degraded by microbial activity over time. A trial was established in 2016 to evaluate the effects of delayed herbicide activation on three products used for kochia management in North Dakota. The trial was established as a split-split plot RCBD with activation strategy as main plot, tillage as subplot and herbicide as sub-sub plot. Activation strategies were adding 0.5" water immediately, adding 0.5" 7 DAT, rotary hoeing 7 DAT, and no activation Tillage treatments were no-till and conventional till. The herbicides were sulfentrazone, metribuzin, and flumioxazin + pyroxasulfone. A PRE glyphosate burn-down was included in all treatments. There were 16 days between herbicide application and the first activating rainfall (1.5"). Common lambsquarters and redroot pigweed were evaluated to measure treatment success. Most treatment combinations resulted in >80% weed control The largest reduction in weed control occurred when activation was delayed for metribuzin (both 7 DAT and the no activation check), particularly in no-till. Rotary hoeing metribuzing treatments did not improve weed control but actually reduced weed control in tilled treatments compared to the no activation check. Conversely, rotary hoeing improved sulfentrazone efficacy in tilled plots compared to the check. Sulfentrazone performance did not decline due to a 7 day delay in activation. Flumioxazin + metribuzin is most at-risk of reduced efficacy under conditions of limited water, and corrective measures such as light tillage after planting cannot be recommended.

Weed Control and Crop Response in Dicamba Tolerant Soybean. Gregory J. Endres*[1], Michael Ostlie[2], J. Paulo Flores[2]; [1]NDSU, Carrington, ND, [2]North Dakota State University, Carrington, ND (147)

A field research trial and demonstration were managed at the NDSU Carrington Research Extension Center in 2016 to generate data and provide educational opportunities on weed control and crop response in dicamba tolerant soybean. The trial examined weed control in dicamba tolerant soybean with selected soil-applied herbicides followed by POST Engenia plus glyphosate (herbicides used at labeled rates and included proper adjuvants). Sequential herbicide application, when visually evaluated about 2- and 4-wk after treatment, was required to provide good to excellent control (88-99%) of yellow foxtail, common lambsquarters, and redroot and prostrate pigweed compared to control with only soil-applied herbicides. PRE Verdict plus Zidua, Authority ATZ, Sharpen plus Boundary, or Zidua Pro followed by POST Engenia plus Roundup PowerMax provided excellent control (89-99%) of wild buckwheat. Also, early POST Engenia plus Roundup PowerMax provided 93-99% control of wild buckwheat. Soybean tolerance to all herbicide treatments was excellent. A weed management trait demonstration using conventional, Roundup Ready, Liberty Link, and dicamba tolerant soybean plus respective POST herbicides provided a site for ag audiences to view crop tolerance and explore the traits as herbicide-resistant weed management tools.

Xtend Crop System. Chris M. Mayo*; Monsanto, Gardner, KS (148)

Monsanto has been working on the development of dicamba-tolerant crops for over ten years. Dicamba-tolerant cotton and soybeans, included in the Roundup Ready® Xtend Crop System, are anticipated to be the largest launch of a biotechnology and crop protection system in history. The Roundup Ready® Xtend Crop System includes an innovative new formulation of dicamba that has industry leading low-volatility technology, comprehensive application requirements for on-target applications and effective and sustainable weed management recommendations. This presentation highlighted some of the application requirements that must be followed for proper use of the technology.

Biology and Management of Scouringrush in Dryland Winter Wheat. Blake D. Kerbs[1], Andrew G. Hulting*[1], Drew Lyon[2]; [1]Oregon State University, Corvallis, OR, [2]Washington State University, Pullman, WA (163)

Scouringrushes (*Equisetum hyemale* L.; *E.* x*ferrissii* Clute; *E. laevigatum* L.) are ancient perennial seedless vascular plants historically associated with wetlands, low-lying roadsides or field margins where there are large levels of plant available water. There has been little research conducted on scouringrush species in the context of agricultural production because traditional farming practices confined them to field margins and roadside depressions. An increasing amount of dryland winter wheat (*Triticum aestivum* L.) hectares in the inland Pacific Northwest have had summer tilled-fallow rotations replaced with chemical fallow. Where chemical fallow rotations have become the standard practice, scouringrush has expanded out of its historical habitat into production fields and established at high enough densities to cause concern from growers. Research was conducted to identify control options that fit chemical fallow cropping systems, evaluate the magnitude of crop interference by scouringrush, and address how soil pH affects scouringrush growth and establishment, as soil acidification is another agronomic issue caused by intensive wheat production in the Pacific Northwest. Field studies located in Reardan, WA, and near The Dalles, OR, were established in commercial wheat production fields that evaluated 10 herbicide treatments for efficacy on scouringrush. An additional factor in the trials was to determine if pre-herbicide application mowing affected herbicide efficacy. At both locations pre-herbicide mowing had no effect on efficacy and only chlorsulfuron plus MCPA-ester controlled scouringrush though the subsequent winter wheat rotation. A third herbicide trial determined that triclopyr or increased rates of chlorsulfuron plus 2,4-D and dicamba or asulam were able to effectively control scouringrush seven and 10 months after treatment at a non-crop site in eastern Oregon. Under field conditions wheat yield reductions were correlated with increasing scouringrush density, but in a controlled study scouringrush density had no effect on winter wheat development or grain yield. Results from three greenhouse studies showed that scouringrush biomass production increased as soil pH increased from approximately 4.6 to 8.0 but that scouringrush was able to establish and survive in very low soil pH conditions that are unsuitable for winter wheat production.

Confirmation and Mechanism of Resistance to Imazamox in Downy Brome (*Bromus tectorum* L.) from Montana. Vipan Kumar*[1], Prashant Jha[2], Anjani J[1], Shane Leland[1]; [1]Montana State University, Huntley, MT, [2]Montana State Universityn, Huntley, MT (164)

Downy brome (*Bromus tectorum* L.) is an invasive winter annual grass weed in crop, range, and pasture lands across the Western US, including Montana. During summer 2016, a downy brome population with putative resistance (R) to imazamox (Beyond®), an acetolactate synthase (ALS) inhibitor, was collected from a winter wheat (Clearfield®) field, near Hammond, MT, where imazamox has been used to control downy brome over >5 yr. The objectives were to confirm and characterize the level of imazamox resistance in R downy brome population relative to a susceptible (S) population, and investigate the underlying mechanism of resistance. The S downy brome population was collected from the research farm at the Montana State University Southern Agricultural Research Center, near Huntley, MT. Whole-plant dose–response experiments indicated that the R population had approximately 98-fold level of resistance relative to the S population on the basis of percent control ratings (I_{50} values). On the basis of shoot dry weight response (GR_{50} values), the R downy brome exhibited resistance index (R/S) of 121-fold. A pre-treatment of R downy brome with malathion (cytochrome P450 inhibitor) did not alter the resistance phenotype for imazamox, most likely ruling out the possibility of a non-target site resistance mechanism in this population. The sequence analysis of *ALS* gene in R plants exhibited a single-point mutation from G to A, conferring a change of the amino acid serine to asparagine at codon 653. Therefore, we propose that a Ser653 to Asn653 substitution in the *ALS* gene confers high levels of resistance to imazamox in the R downy brome population. This is the first report on the evolution of imazamox-resistant downy brome identified in Montana, USA, and first confirmation of this target site (*ALS* gene) mutation (Ser_{653} to Asn) as a mechanism of ALS resistance in this weed species.

Bicyclopyrone + Bromoxynil: Broadleaf Weed Control in Cereals. Peter C. Forster*[1], Donald J. Porter[2], Monika Saini[3]; [1]Syngenta Crop Protection, Eaton, CO, [2]Syngenta Crop Protection, Greensboro, NC, [3]Syngenta, Greensboro, NC (165)

Syngenta has developed a new selective postemergence herbicide for the US market that provides broad spectrum broadleaf weed control in wheat and barley. This herbicide premix (brand name Talinor™) contains two active ingredients with multiple modes of action, Bicyclopyrone, an HPPD inhibitor (Site of Action Group 27), and Bromoxynil, a PS II inhibitor (Site of Action Group 6). In field trials conducted over multiple years, bicyclopyrone + bromoxynil at 212.5 to 283.3 g ai/ha combined with an additive (CoAct+™) at 64 to 84 g ai/ha provided excellent control of some of the more troublesome broadleaf weeds in cereals, such as Russian thistle, kochia, wild buckwheat, prickly lettuce, nightshade species, lambsquarters, pigweed species and mayweed chamomile, including populations that are resistant to ALS-inhibitor and synthetic auxin herbicides. Bicyclopyrone + Bromoxynil herbicide received federal approval for use in all varieties of spring wheat, winter wheat, durum and barley in November of 2016. State approvals are in process.

Hyperspectral Imaging to Detect Herbicide-Resistant Weeds In-Crop: Convergence of Optical and Ag Technologies. Prashant Jha*[1], Joe Shaw[2], Vipan Kumar[1], Paul Nugent[2]; [1]Montana State University, Huntley, MT, [2]Montana State University, Bozeman, MT (166)

Advanced optics-based hyperspectral imaging could be a potential tool for early detection of herbicide-resistant weeds in-crop and for site-specific precision weed control. A hyperspectral image has large number of pixel spectra; therefore, image segmentation is executed pixel by pixel. This technology has the possibility of weed detection at a high rate of accuracy because the image contains more detailed spectral information and much higher resolution compared to Red, Green, and Blue (RGB) or multispectral imaging. This project is focused on the development of hyperspectral imaging and smart algorithms to distinguish between herbicide-resistant and susceptible kochia in-crop. The crops include wheat, barley, and sugar beet. Our hyperspectral imager in the wheat/barley/sugar beet field was used to record hyperspectral data cubes with 240 spectral channels per spectrum over the wavelength range of 396 – 885 nm (visible to near-infrared). Such images obtained from the ground or from an aerial platform (UAVs), can be used to create maps that show growers where spot spraying (site-specific weed control) is required. This allows much more economical application of herbicide than broadcast spraying and also helps identify problem spots/patches with herbicide-resistant weeds in-crop. The pixel discrimination model between crop and kochia biotypes consisted of normalization, generation of explanatory variables and discrimination, and different types of models were developed and validated. The smart algorithms were based on machine learning classifiers, where various spectral features were used to map the locations of different biotypes of kochia in a crop field. The results indicate that glyphosate-resistant and dicamba-resistant kochia biotypes can be differentiated from a susceptible kochia biotype in a sugar beet, barley, or wheat field based on differential spectral reflectance across visible (520 to 650 nm) and near-infrared (720 nm) wavelengths.

Decomposition of *Brassicaceae* Residues Under Different Tillage Methods and the Impacts on Ascospore Survival and Spread in the Crop. Pete A. Berry*; Oregon State University, Corvallis, OR (167)

The disease black leg has been identified on *Brassicaceae* crops and weeds in Oregon. Because black leg can survive in *Brassica* crop residues, ascospore movement from these residues to subsequent crops or alternate weed hosts is a concern. Mechanical treatments consisting of shallow tillage, no-till, and flailing, were applied after harvest to turnip, forage rape, and canola residues to compare decomposition rates. Mesh bags filled with residues were placed on the surface or buried at 5 cm. The below ground residues and structural components were measured after 9 months. For turnip, the remaining residues in shallow-tillage, no-till, and flailing were 36, 41, and 38%, respectively. Structural components of hemi-cellulose, cellulose, and lignin were 17, 35, 21% in shallow tillage, 18, 35, and 21% in no-till, and 16, 32 and 22% in flailing, respectively. For canola, residues remaining in shallow-tillage, no-till and flailing were 38, 47, and 50%, respectively. Structural components of hemi-cellulose, cellulose, and lignin for shallow-tillage were 17, 39, and 18%, no-till 15, 26, and 17%, and flailing 15, 38, and 15%, respectively. For forage rape, residues remaining in shallow-tillage, no-till, and flailing were 47, 38, and 44%, respectively. Structural components of hemi-cellulose, cellulose, and lignin were 17, 42, and 20% in shallow tillage, 17, 43, and 20% in no-till, and 17, 41, and 20% in flailing, respectively. Above ground residues had similar decomposition rates and percent change in structural components. Results of this study indicate that burying residue does not lead to faster decomposition.

A Meta-Analysis of Field Bindweed (Convolvulus arvensis) and Canada Thistle (Cirsium arvense) Management in Organic Agricultural Systems. Noelle Orloff, Fabian Menalled*, Jane Mangold, Miller Zachariah; Montana State University, Bozeman, MT (168)

Organic farming has become a major agricultural and economic sector, and weed management is one of the primary challenges facing the industry. Of particular concern are rhizomatous perennial weeds such as field bindweed (*Convolvulus arvensis*) and Canada thistle (*Cirsium arvense*) which are highly competitive and not easily controlled in organic systems. We conducted meta-analyses of the existing literature to 1) identify promising management approaches for these weeds in the absence of synthetic herbicides and 2) determine which aspects of field bindweed and Canada thistle management warrant further study. Mechanical control (i.e. tillage) was the most studied management technique in annual cropping systems, accounting for 40% of data extracted, but did not outperform most of the other management actions. In annual systems, integrated management, or the combination of two or more control methods, emerged as the management technique that caused the greatest decrease in abundance and survival for field bindweed. We identified several additional management techniques that decreased field bindweed and/or Canada thistle in both annual and perennial systems including biocontrol, mowing, grazing, crop diversification, solarization, shading, flaming, and crop competition. However, organic producers continue to struggle with these species. This discrepancy may originate from the fact that most of the studies we evaluated reported impacts over short time spans, with 53% being conducted for a period of one to two years, and only 9% conducted for five or more years. Further, only 16% of field bindweed and 26% of Canada thistle studies reported measures of variability. Longer-term research focused on sustainable perennial weed management systems is needed in addition to research about short-term interventions.

PROJECT 4: TEACHING AND TECHNOLOGY TRANSFER

Weed Science in China: Opportunities and Challenges. Zhaohu Li*; China Agricultural University, Beijing, Peoples Republic (158)

Abstract not available

Assessing Inexpensive Temperature Loggers: Do They Provide Good Data? Dirk V. Baker*; Campbell Scientific, Inc, Logan, UT (159)

Miniature dataloggers with integrated sensors can be very useful as a low-cost means of obtaining replication and spatially distributed measurements. However, users rarely assess the precision and accuracy of equipment before purchase or before deployment.

To assess accuracy and precision as well as demonstrate a method, five each of three types of temperature loggers (UA-001-64, DS1921G, DS1922L) were placed in an environmental chamber along with calibrated references (CR6, 109 thermisters). Temperature was varied from -20 to 50 C at 5 degree increments and held at each increment for one hour to ensure enough time for equilibration.

All loggers were generally within 0.5 degree C of the reference as well as each other during times when temperatures were stable. Not surprisingly, however, the accuracy and precision were lower (1 to 2 degrees C) when temperature was changing rapidly.

Under relatively ideal conditions, these loggers should perform well. However, there can be a great deal of error associated with the installation of any sensor. For instance, errors of several degrees C in air temperature measurements have resulted from inadequate or lack of shielding from solar radiation.

It is vital when using any instrumentation is to verify all the sensors agree with each other under the same conditions and to use this information both in experimental planning and in subsequent analyses. Preferably, calibration checks should be conducted both before and after deployments, but can be as simple as one to three points that represent the range of interest. Minimally, the specifications published by manufacturers should explicitly be taken into consideration during planning, analyses, and publication.

Does Pulse-Sprayer Technology Affect Herbicide Efficacy? Kirk A. Howatt*[1], Michael J. Christoffers[1], Thomas J. Peters[1], Jason W. Adams[2]; [1]North Dakota State University, Fargo, ND, [2]North Dakota State University, FARGO, ND (160)

Off-target particle drift is widely considered preventable through adjustment of application equipment for larger droplet size. Research to quantify pesticide efficacy resulting from different spray characteristics and application technologies, such as pulse-width modulation (PWM) sprayers, will allow growers to effectively use new herbicide technologies while reducing off-target herbicide movement. A series of experiments were conducted to evaluate weed control with herbicides applied through a PWM sprayer at various droplet sizes, travel speeds, and duty cycles compared to conventional broadcast application. Weed control varied widely depending on specific herbicide, application travel speed, and droplet size; however, duty cycle did not appear to be a primary influence. Waterhemp control in sugarbeet tended to be less as travel speed increased. Less weed control at faster travel speed also was present with most of the wheat herbicides tested. In all experiments with broadleaf herbicides for wheat, treatments applied through conventional small-plot research methods of continuous pressure, 300µm droplet size, and 4 mph travel speed were consistently in the group providing the greatest weed control. Compared with the handboom, the PWM sprayer provided similar control at either droplet size at speeds less than 6 mph. Traveling 12 mph typically resulted in less weed control. At this higher speed, a separation between droplet sizes was evident with 5 to 10% less control using 300µm droplets and 10 to 20% less control using droplets near 750µm. Potential for PWM sprayer to enhance selection for herbicide resistance in wild oat was evaluated. Use of pulse spray settings resulted in more survival following pinoxaden application than with conventional settings. Promotion of larger droplet size for drift mitigation needs to be tempered to allow for better weed control with some herbicides at medium to coarse droplet sizes. Additional research is planned to further our understanding of these preliminary findings and confirm results.

Framing Herbicide Resistance – How Farmers Employ Techno-Optimism to Justify Reliance on Herbicidal Weed Management. Katherine Dentzman*; Michigan State University, East Lansing, MI (161)

US corn and soybean farmers' use of herbicides as the primary, or even singular, method of weed control persists in spite of increasing concern over herbicide resistance. Additionally, recommendations by academic extension agents to incorporate more integrated management practices have seen relatively little adoption. Reasons cited for this reticence to move way from chemical-dependent weed control include high costs and a belief that new chemical herbicides will be developed to take the place of those that are no longer effective (Bonny 2016; Livingston et al. 2016; Norsworthy et al. 2012; Webster and Sosnoskie 2010). However, such beliefs are being challenged by the lack of discovery of any new herbicide mode of action in the last 20 years, a trend which seems unlikely to change in the near future. This paper addresses farmers' apparent trust in chemical weed control, asking why farmers trust chemical herbicides and eschew integrated weed management, as well as how they justify a chemical-dependent weed management plan to themselves and others. To answer these questions, I draw on the literatures of sociotechnical imaginaries, master frames, and frame keying. I propose that farmers' seeming trust in chemical technology is an 'as-if' trust (Carolan 2006; Wynne 1992) that farmers justify to themselves and others through keying of master frames that are iteratively supported by the dominant sociotechnical imaginary of weed control in US industrial farming.

The Herbicide Property Tool (HPT) from the National Pesticide Information Center at Oregon State University can be Useful in Teaching, Research and Extension activities. Kaci J. Buhl*, Brittany Hanson, Alicia Leytem, Sean Ross; Oregon State University, Corvallis, OR (162)

A new web app contains physical/chemical properties of herbicides, and groundwater ubiquity scores. The Herbicide Property Tool (HPT) was developed at the National Pesticide Information Center at Oregon State University, through a cooperative agreement with the US EPA. The web-based platform includes over 200 herbicidal active ingredients, and references documenting their solubilities, binding affinities, half-lives in different soil types, and more. Animations and fact sheets define the meaning behind the numbers. Customize the table view and print results. Values were collected from EPA risk assessments whenever available, and relative groundwater risk was calculated in three soil types for each herbicide, when sufficient data were available. The speaker will demonstrate how to use the tool in teaching, research, and extension activities.

PROJECT 5: BASIC BIOLOGY AND ECOLOGY

A Draft Genome for *Kochia scoparia*. Todd A. Gaines*[1], Eric L. Patterson[1], Dean Pettinga[1], Karl Ravet[1], Daniel Sloan[1], Patrick Tranel[2], Phil Westra[1], Christopher Saski[3]; [1]Colorado State University, Fort Collins, CO, [2]University of Illinois at Urbana–Champaign, Champaign, IL, [3]Clemson University, Clemson, SC (056)

Kochia scoparia (kochia) is one of the most important weeds in the western United States and Canada. It currently infests hundreds of thousands of acres of farm and range land across North America and causes millions of dollars in crop loss annually in sugar beet, canola, wheat and corn fields. *K. scoparia* has evolved resistance to many of the most important herbicides used for its control, including glyphosate, dicamba, and ALS inhibitors. Additionally, *K. scoparia* is an extremely hardy plant that can tolerate substantial abiotic stress from drought, salt, and both extremes of temperature. This suite of traits all contribute to its success as a weed. Our research aims to make *K. scoparia* a model organism, not only for weed research but also as a plant extremophile. Initial analysis of Illumina genomic DNA reads suggested that the *K. scoparia* genome is highly complex. To circumvent problems surrounding highly repetitive regions of the genome we are utilizing a hybrid low coverage PAC-BIO and high coverage Illumina approach. Currently, we have assembled approximately 83% of the genome with 711 Mb in 19,671 scaffolds. Our initial ALL-Paths assembly suggests that *K. scoparia* contains substantial sequence duplication throughout the genome and that this may lead to rapid genome evolution and increased genetic diversity at key loci involved in abiotic stress response. EPSPS is a tandemly duplicated gene that confers resistance to glyphosate in some *K. scoparia* populations. The EPSPS gene has been identified within an assembled sequence contig.

Use of SSR Markers to Track the Evolutionary Trajectory of Glyphosate Resistant Kochia in North America. Adrian Quick*[1], Todd Gaines[2], Phil Westra[2]; [1]Colorado State University, Ft. Collins, CO, [2]Colorado State University, Fort Collins, CO (057)

Kochia scoparia has evolved glyphosate-resistance (GR) by gene amplification of the target gene 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), enabling the plants to survive the field rate of glyphosate application. GR in *K. scoparia* has progressed on a rapid temporal scale, meaning that evolution of resistance occurred over the course of relatively few generations. By taking advantage of our ability to access GR and glyphosate-susceptible (GS) populations from throughout the US and Canada, we are conducting a population genetics study to 1) establish the dynamics of GR evolution through populations, and 2) to determine whether there was a single origin of GR *K. scoparia* that has then radiated throughout the region or whether GR emerged multiple times independently at different locations. For this work, we collected over the five past years GR and GS *K. scoparia* populations from KS, CO, NE, WY, MT, and TX in the US, as well as populations from Alberta and Saskatchewan, Canada. Populations were assessed for GR in greenhouse conditions at field rate glyphosate application. EPSPS copy number was quantified by genomic qPCR and Droplet Digital PCR (ddPCR). We utilized Simple Sequence Repeat (SSR) DNA markers to determine relatedness of GR and GS populations. The multiallelic and highly polymorphic nature of SSR markers is of particular value when analyzing closely related kochia populations. SSR fragments were amplified by DNA Polymerase Chain Reaction (PCR) and DNA product size was analyzed by gel capillary electrophoresis. From 36 populations, 472 individuals were genotyped for 12 SSRs. All together, our results should infer the number of origins of the resistance phenotype and the dynamics of evolution of GR throughout North America.

Diversity of Russian-thistle (*Salsola tragus* L.) in the Pacific Northwest. John F. Spring*[1], Drew J. Lyon[1], Caleb C. Squires[2], Ian C. Burke[1]; [1]Washington State University, Pullman, WA, [2]Washington State University, Pullman, WA, WA (058)

As a species, Russian-thistle is characterized by high levels of morphological variability on global, continental, and regional scales. Previous research in California found this variability encompassed a cryptic complex of five distinct species in populations of *Salsola* in that state. Russian-thistle is a highly problematic weed in the dryland wheat-fallow production region of the Inland Pacific Northwest, where it also exhibits high levels of morphological variability. Anecdotal field observations of this variability suggest that substantial levels of genetic differentiation and population structure may be present in this region. The present study used a genotyping-by-sequencing approach to characterize the genetic diversity and population structure of Russian-thistle in the inland Pacific Northwest. Double digest RAD-seq libraries were created from 94 individual plants collected by systematic randomized sampling across the wheat-fallow production region of Washington and Oregon. Only one species (*Salsola tragus*) was found. Multi-dimensional scaling, kernel-PCA-and-optimization population clustering, and Moran's eigenvector mapping approaches all indicate the presence of a single, unstructured population across the region. High levels of standing genetic diversity were indicated in this population by multilocus expected heterozygosity of 0.349. While rather unexpected, this conclusion seems biologically feasible in a species with high effective population size and high migration rates.

Effect of Crop Canopy on Kochia (*Kochia scoparia*) Seed Production. Elizabeth G. Mosqueda*[1], Andrew R. Kniss[1], Gustavo Sbatella[1], Prashant Jha[2], Nevin C. Lawrence[3], David A. Claypool[1]; [1]University of Wyoming, Laramie, WY, [2]Montana State Universityn, Huntley, MT, [3]University of Nebraska-Lincoln, Scottsbluff, NE (059)

Kochia (*Kochia scoparia*) is one of the most problematic weeds in the western United States. It has evolved resistance to several herbicide sites of action, making it critical to find alternative, sustainable methods to control kochia. Previous studies have shown impacts of crop canopy on various weed species development, however, there are few direct comparisons of different crops for their ability to suppress kochia seed production. A field study was initiated in 2014 near Lingle, Wyoming to evaluate the effect of crop canopy on kochia seed production. Crops used in this study were spring wheat, dry bean, sugarbeet, and corn. Kochia seed was spread within each plot at a rate of 2,000 g/ha approximately two weeks prior to planting crop seed. Kochia seed was collected at crop maturity. ANOVA and Fisher's LSD were used to analyze data and separate means. No kochia were found in any of the spring wheat plots, so it was not included in our statistical analysis.

Dry bean and sugarbeet were the least competitive crops, allowing kochia to produce an average of 64,856 and 44,629 germinable weed seeds/plant, respectively. Corn was significantly more competitive, allowing 7,730 germinable weed seeds/plant. However, spring wheat allowed no kochia plants to establish, suggesting it was the most competitive crop even though it was excluded from the analysis.

The Basis of Glyphosate Resistance in "Rapid Necrosis" Giant Ragweed Populations. Phil Westra*[1], Christopher VanHorn[2], Todd Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Colorado State University, Ft. Collins, CO (060)

Glyphosate resistant giant ragweed (*Ambrosia trifida)* has evolved across a broad geographic region of the United States and Canada, causing very serious crop losses where it cannot be controlled. At Colorado State University, we have conducted greenhouse and basic molecular research on 20 diverse accessions of giant ragweed including a large RNAseq study. There is a highly unusual phenotypic glyphosate resistance response in many of these accessions characterized by a very rapid death and desiccation of mature plant leaves, often manifest within a few hours to one or two days. Such a response is not observed when treated plants are placed in the dark, leading to the hypothesis that an energy source is required to drive the response. Feeding selected aromatic amino acids through the roots protects plants from the rapid necrosis. Hydrogen peroxide builds up in treated mature leaves in 15 – 30 minutes after glyphosate treatment causing massive cell destruction. This response to glyphosate is highly unusual and perplexing. The net effect, however, is a massive rapid amputation of glyphosate laden mature leaves, resulting in new growth from meristem tissues which are not affected. The RNAseq experiment yielded a number of candidate genes that may be involved in this glyphosate response in giant ragweed.

Effects of Reflected Light Quality on Growth and Photosynthate Partitioning in *Beta vulgaris*. Albert T. Adjesiwor*[1], Andrew R. Kniss[2]; [1]University of Wyoming, Laramie, WY, [2]University of Wyominig, Laramie, WY (061)

Reflected light from plant canopies has a reduced red (R) to far-red (FR) ratio. Plants are able to sense changes in R:FR and modify their morphology and physiology which can affect growth and yield even in the absence of direct resource competition. Little is known about the effects of reflected light quality on *Beta vulgaris* L. This study evaluated effects of reflected FR from grass (Kentucky bluegrass) on growth, morphology, and non-structural carbohydrate (NSC) partitioning of *Beta vulgaris*. Grass was clipped frequently to prevent shading and competition for light. Roots of grasses were isolated from *B. vulgaris* to ensure there was no competition for water and nutrients. *B. vulgaris* was harvested at 15, 32, 50, and 77 days after planting (DAP). Relative to the control (no grass), there were longer cotyledons (2.2 vs 1.5 cm), wider cotyledons (0.6 vs 0.5 cm), and greater cotyledon surface area (1.8 vs 1.0 cm^2) in the grass treatment at 15 DAP. Presence of grass beyond 15 DAP generally resulted in reduced number of leaves and root fresh weight in *B. vulgaris*. Leaf area was, however, not influenced by treatments beyond 15 DAP (P-value = 0.31). There were three less leaves in the grass treatment compared to the control at final harvest (77

DAP). The grass treatment significantly reduced root fresh weight (*P*-value = 0.02) by15 to 48 %, when *B. vulgaris* was harvested at 32, 50, and 77 DAP. Soluble carbohydrates (CHO), starch, and total NSC (soluble CHO + starch) were generally not influenced by treatments. However, for both roots and shoots, starch decreased while soluble CHO increased with increase in age of *B. vulgaris*. These results showed that reflected light quality may reduce *B. vulgaris* growth in the absence of direct competition for resources.

Effect of Seed Treatments on Sugar Beet Germination under Far-Red Light. David A. Claypool*, Andrew R. Kniss; University of Wyoming, Laramie, WY (062)

The effects of existing plants on crop germination and emergence are still largely unknown. Although relatively little light penetrates through soil, red and far-red light are more likely to penetrate deeply compared to shorter light wavelengths. Studies conducted by several researchers in the 1980s (reviewed by Tester & Morris, 1987) indicate that light can penetrate deeply enough to impact shallow planted crops like sugarbeet (*Beta vulgaris*). Previous research suggests that some varieties of sugarbeet seed are inhibited by far-red light, but that different seed treatments may alter the response to far-red light. The objective of this study was to determine whether sugarbeet seed pelleting or pesticide treatments would alter seed germination responses in the presence of far-red light. The effect of a vigorous weed or cover crop canopy at the time of sugarbeet planting was simulated by the use of far-red light. Germination studies were conducted to determine the direct impact of light quality on seed germination. Two light treatments were used: low light (LL) and low light plus supplemental far-red light (FR). In each light treatment, six seed preparations were applied to the same sugarbeet variety (‘Betaseed BTS 60RR27'): 1) unpelleted and untreated, 2) small pellet with no pesticide seed treatment, 3) medium pellet with no pesticide seed treatment, 4) large pellet with no pesticide seed treatment, 5) unpelleted seed treated with Cruiser Maxx[â], 6) unpelleted seed treated with Poncho Beta[â]. Pesticides were applied at the authors’ request and are not commercial or registered seed preparations. In Study 1, 25 sugarbeet seeds of each seed preparation were placed in petri dishes with seed germination paper; each seed and light combination was replicated 4 times. Germinated seed was counted and removed daily. Seed was defined as germinated if the radical or cotyledons had emerged 1 mm from the seed coat or pellet surface. The germination data was then fit to a Weibull function. From each model, the maximum germination and germination speed were estimated. Maximum germination was the proportion of seed that germinated during the course of the experiment. The speed of germination was estimated by calculating the number of days required to reach 50% germination; higher values mean slower germination. Study 2 was conducted to determine the impact of seed pellet size on speed of radicle growth. Methods were as previously described except 10 seeds were used. After 72 hours, the study was terminated, each dish was photographed, and the digital photos were analyzed using “ImageJ” software to measure sugarbeet radicle length. Two-way ANOVA was used to determine the impact of light and seed treatments on total germination and radicle length. Exposing sugarbeet seed to far-red light significantly reduced germination speed and maximum germination in all treatments. Germination speed ranged from 1.5 to 4.6 days for LL and 2.3 to 7.6 days for FR. Maximum germination ranged from 84 to 98% for LL and 57 to 91% for FR. Far-red light significantly reduced radicle length of germinated seed for each pellet size when measured 72 hours after planting with a mean reduction of 5 mm. Radicle length ranged from 12 to 16mm for LL and from 7 to 11mm for FR. No seed treatment used in the study had any impact on sugarbeet seed response to far-red light as measured by total germination, germination speed, or 72-hr radicle length. The results of this research suggest that the tested seed preparations are unlikely to negate the potential impact of weed or cover crop canopy at the time of sugarbeet planting.

Influence of Soil Type and Growing Environment on the Selectivity Index in Herbicide Resistance Studies. Carl W. Coburn*, Andrew R. Kniss; University of Wyoming, Laramie, WY (063)

The selectivity index (SI) can be used to quantify herbicide resistance, and it is important to understand how experimental factors may influence it. Experiments were conducted in a greenhouse and outdoors in Sheridan, WY, and in a greenhouse in Laramie, WY, to determine the effect of soil type, growing environment, and response variable on the SI of glyphosate-susceptible and -resistant kochia (*Kochia scoparia*). Biotypes were planted in pots containing either potting media or field soil in each of the three growing environments. Glyphosate was applied at rates ranging from 0 to 2400 g ae ha^{-1} to glyphosate-susceptible kochia or at rates ranging from 0 to 4000 g ae ha^{-1} to glyphosate-resistant kochia. Above ground dry weight, injury, and mortality were assessed 28 days after treatment (DAT). A log-logistic model was used to quantify the response of each biotype to glyphosate. ED_{50} estimates (effective dose resulting in 50% response) for the resistant biotype were higher in potting media compared to field soil. SI values were always higher when plants were grown in potting media compared to field soil. Dry weight resulted in the most variability in SI across growing conditions. There was no clear trend in SI values across growing environments. These results imply dose-response experiments conducted in potting media may overestimate differences in herbicide sensitivity between biotypes compared to field soil.

Seed Germination Requirements for Venice Mallow (*Hibiscus trionum*) Populations from Northwestern Wyoming. Gustavo M. Sbatella*; University of Wyoming, Powell, WY (064)

Venice mallow populations are found infesting agricultural fields in northwest Wyoming, and it is particularly difficult to control in dry beans causing significant economic losses. Species with an extended germination pattern such as Venice mallow often escape control efforts. A better understanding of the germination requirements for the species can help develop more efficient control strategies. For these reasons, studies were conducted at the Powell Research and Extension Center to characterize the effects of constant (5, 10, 15, 20, 25 and 30 C) and alternating (5-15, 15-25, and 20-30 C) temperatures on Venice mallow seed germination. Seeds were collected from 8 populations growing near Powell and Burlington, WY. Fresh harvested seeds exhibit a high level of physical dormancy (99%). The most efficient method to scarified seeds was immersion for 0.5 h in concentrated sulfuric acid. No germination was recorded at constant 5 C. High levels of germination were recorded for constant temperatures of 15, 20, and 25 C. Seed germination rates varied for each temperature, and also differed between populations. Germination levels of 80% or higher were observed with alternating temperatures of 15-25, and 20-30 C, suggesting that the optimal temperature for the Venice mallow populations collected in northwest Wyoming is between that temperature range.

Integrated Weed Management of Winter Annual Grasses in Wheat using Harvest Weed Seed Control. Neeta Soni*[1], Scott Nissen[1], Philip Westra[2], Michael Walsh[3], Jason K. Norsworthy[4], Todd Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Colorado State University, Ft. Collins, CO, [3]University of Sydney, Sydney, Austria, [4]University of Arkansas, Fayetteville, AR (065)

Feral rye (*Secale cereale*), downy brome (*Bromus tectorum*), and jointed goatgrass (*Aegilops cylindrica*) are troublesome winter annual grasses that are common in Colorado wheat fields. Besides conventional practices (such as herbicides and crop rotation), new approaches are needed to provide better integrated weed management. Harvest weed seed control (HWSC) methods are intended to prevent the reintroduction of weed seed in the agriculture field when the crop is harvested. Currently, the method where most of the research is focusing is the Harrington seed destructor (HSD) due to effectiveness and agroecological benefits. In order for the HWSC methods to be successful, weed and crop species need to have similarities in growth habit. Feral rye, downy brome and jointed goatgrass have similar height and reach maturity at the same time as wheat. Thus, our hypothesis was that the largest percentage of weed seed would be retained in the harvestable wheat fraction of the canopy. In addition, we proposed that most of the weed seed could be destroyed by the HSD prototype. To test these hypotheses, we quantified and compared the amount of weed seed found in the upper wheat canopy versus the shattered weed seed on the soil. Moreover, we quantified the percentage of weed seed damaged by the HSD prototype. During 2015 and 2016, 40 wheat fields in eastern Colorado were sampled 2-5 days before harvest. Four samples were collected in each field. Plant height and seed amount in both the above 15 cm fraction of the wheat canopy and on the soil surface were quantified per weed species. Additionally, weed seed viability was determined after processing wheat chaff with seed of each species through the HSD. Results showed that greater than 75% of downy brome, feral rye and jointed goatgrass seed were retained in the wheat harvestable section. The HSD showed good potential as a HWSC method for the studied weed species. As an integrated weed management practice, HWSC could dramatically reduce the weed seed bank and consequently reduce herbicide use and improve management of herbicide resistance without jeopardizing crop productivity.

Harvest Weed Seed Control in Western Canada: Identifying Target Species. Breanne D. Tidemann*[1], Linda M. Hall[2], K. Neil Harker[1], Hugh J. Beckie[3], Eric N. Johnson[4], F. Craig Stevenson[5]; [1]AAFC, Lacombe, AB, [2]University of Alberta, Edmonton, AB, [3]AAFC, Saskatoon, SK, [4]University of Saskatchewan, Saskatoon, SK, [5]Private Consultant, Saskatoon, SK (066)

As selection of herbicide resistant weeds increases, chemical management options become increasingly limited and the investigation of non-chemical tools becomes necessary. Harvest weed seed control (HWSC) targets and destroys weed seeds that are otherwise dispersed by harvesters following threshing. While there is interest in Canada in the use of these methods, it is not known whether problem weeds in western Canada retain their seeds until harvest at a height suitable for collection. A study was conducted at three sites over 2 years to determine if retention and height criteria were met by wild oat, cleavers and volunteer canola. Wild oat consistently shed seeds early, but seed retention was variable, averaging 56% at the time of wheat swathing with continued losses until direct harvest of wheat and fababean. The majority of retained seeds were well above ground level and easily collected. Cleavers seed retention was highly variable by site-year, but generally greater than wild oat. The majority of retained seed would be collectable by the harvester. Canola seed was highly retained on the plant, with >95% retention in most cases and nearly all seed retained >45 cm above the ground. The suitability ranking of the species for management with HWSC was canola > cleavers > wild oat. Efficacy of HWSC systems in western Canada will depend on the target species and site- and year-specific environmental conditions.

Cytochrome P450 Metabolism of Fenoxaprop-p-ethyl in Wheat and Barley. Caleb C. Squires*, Arron H. Carter, Ian C. Burke; Washington State University, Pullman, WA (067)

P450 monoxygenases are known to be an integral part of herbicide metabolism pathways. A P450 involved in metabolism of the herbicide fenoxaprop-p-ethyl in barley has been identified and is here characterized. Expression analysis of a mutant line derived from cv. Morex, identified a P450 deletion. The P450 segregated with the sensitive phenotype in a Morex/Mutant population. Genomic and cDNA sequences were obtained from 7 barley cultivars, allowing determination of consensus sequences, and identification of introns and exons. Specific metabolism of fenoxaprop-p-ethyl, and not other ACCase herbicides was demonstrated. Fenoxaprop-p-ethyl and its metabolites were examined by LC/MS after application on wild-type Morex, and the sensitive mutant. Differential fenoxaprop metabolism was confirmed. Deployment of this fenoxaprop-p-ethyl sensitivity trait in barley has potential for removal of unwanted barley from other grass crops such as wheat.

An Update on the Evaluation and Development of Physical Drift Reduction Adjuvants, Vapor Drift Reduction Adjuvants and Physical and Vapor Reduction Combination Adjuvants with Several Dicamba and 2,4-D Formulations. Jim Daniel*[1], Philip Westra[2], Kirk A. Howatt[3], Scott Parrish[4], Trevor Jones[5]; [1]Ag Research Consultant, Hudson, CO, [2]Colorado State University, Ft. Collins, CO, [3]North Dakota State University, Fargo, ND, [4]AgraSyst, Spokane, WA, [5]AgGro Innovations, Cypress, TX (068)

Increased use of phenoxy herbicides with glyphosate to manage herbicide resistance has led to concerns of physical and vapor off target movement of the phenoxy herbicides. Research into new drift and volatility reduction adjuvants has been conducted in multiple greenhouse and field studies for the past three years. Results have been presented in posters at the 2015 and 2016 WSWS meetings. Those results are updated in this presentation with results from 2016 studies. Over 26 greenhouse volatility box trials have shown that AQ 2092 and AQ 2110 significantly reduce vapor damage from 2,4-D dimethyl amine salt to tomatoes and vapor damage from dicamba dimethyl amine salt and diglycolamine salt to soybeans. Seven field trials conducted in Colorado, Texas, and North Dakota have shown these same adjuvants significantly reduce vapor and physical off target movement of these phenoxy herbicides. These products will be commercialized in 2017.

EDUCATION & REGULATORY SECTION

Macro-photography: the Focus Stacking Revolution. Robert F. Norris*; University of California, Davis, CA (156)

The workshop was for anyone who takes photographs of plants, and covered the macro photography revolution that has occurred in the last few years. Principles of macro photography were reviewed prior to discussion of the recent advances. Cameras with high resolution sensors provide extremely detailed views of plants, permitting extensive cropping of images with little loss of detail. Focus stacking, which involves taking a series of photographs with incremental changes in focus point, has removed the limitations in close-up photography imposed by shallow depth of focus. The 'stack' of photographs can be taken using manually adjusted focus points or through the use of software that controls the focus motor built into the camera or the lens. Use of a focusing rail, which moves the camera, improves precision of the stack. For field use, a screw-type manual focusing rail permits accurate focus steps of about 250 µm. For studio use, a motorized focusing rail, in conjunction the appropriate hardware and software, can be completely automated for taking the images composing the stack. Step sizes as small as 2 µm can be achieved. Wi-Fi connections allow smartphones, tablets, or computers, with the appropriate apps, to remotely control all functions of the camera and the focusing rail. Multiple files comprising the 'stack' of photographs are processed to form a single high resolution image using proprietary software. The hardware and software involved was demonstrated. Limitations to the use of focus stacking for plant photography were discussed. All aspects of the presentation were illustrated using photographs of weeds.

Risk Communication. Kaci J. Buhl*; Oregon State University, Corvallis, OR (157)

Abstract not available

Climate Change on Weed Biology, Ecology, and Managament

Climate Change and Weed Biology. Ian C. Burke*[1], Nevin C. Lawrence[2]; [1]Washington State University, Pullman, WA, [2]University of Nebraska-Lincoln, Scottsbluff, NE (169)

Changing climate will affect weed biology, with consequences for invasion and management across the western United States. The Intergovernmental Panel on Climate Change (IPCC) agree in their assessments of how crop yields will respond at a regional scale to rising temperatures, CO_2, and tropospheric O_3 . However, there is less confidence in the IPCC assessment in the response of invasive and agronomically important weeds and of their interaction with ecosystems or crops. The majority of published studies investigating weed response to climate change have focused on two main areas: competition between plants of different photosynthetic functional groups under conditions of increased temperature and CO_2 concentrations, or range shifts of weedy plant species on a regional scale. In order to project changes in weed response to climate change which will be relevant to land managers, projections need to be region specific. However, few papers have investigated the response of weeds to climate change in relation to a specific crop, ecosystem, or region. When predicting how weeds may respond to climate change, critical traits include those regulating plasticity in phenology and flowering time. For example, previous research has suggested the relative differences in development observed among downy brome populations is due to variation in vernalization requirements. In downy brome, the expression of *VRN1,* a major gene controlling vernalization in grasses, was only found in vernalized plants. To fully elucidate the flowering requirements of downy brome, the role of other flowering genes, and the role of day length in regulating downy brome flowering still need to be addressed. Downy brome development and seed set is projected to advance across western United States regardless of the model used or the RCP scenario employed. Land managers will need to adapt to climate change by controlling downy brome earlier, relative to current control measures.

Impacts of Climate Change on Invasive Species Distributions and Interactions with Native Species. Matt Germino*; USGS, Boise, ID (170)

Exotic invasive species and climate shifts are prevalent stressors on ecosystems globally, and their interactive effects may be particularly acute in upland landscapes of the western US. A prevailing paradigm in research and management suggests that the resistance of a plant community to invasion is related to its biotic resilience to disturbances such as fire. Resistance and resilience are related to elevation and site climate, and thus may be predicted to change with climate shifts. These concepts have been developed and evaluated more for exotic annuals than for other herbaceous invaders such as exotic tap-rooted forbs. I will give examples of points of sensitivity in the response of exotic invasive herbs to climate, and will describe how and why the climate responses are often contingent on the resident (native) plant community. Lastly, I will outline practical challenges and potential solutions for managing exotic invaders in a changing climate.

Rangeland Production as Affected by Climate Change. Matt Reeves*; USFS, Missoula, MT (171)

The potential effects of climate change on net primary production (NPP) of U.S. drylands were evaluated using estimated climate regimes from the A1B, A2 and B2 global change scenarios imposed on the biogeochemical cycling model, Biome-BGC from 2001 to 2100. Temperature, precipitation, vapor pressure deficit, day length, solar radiation, CO_2 enrichment and nitrogen deposition were evaluated as influential drivers of NPP. Across all three scenarios, dryland NPP increased by 0.26 % yr^{-1} (7 kg C ha^{-1} yr^{-1}) but the increase was not apparent until after 2030 and significant regional variation in net primary production was revealed. The Desert Southwest and Southwest assessment regions exhibited declines in productivity of about 7% by 2100, while the Northern and Southern Great Plains, Interior West and Eastern Prairies all experienced increases over 25%. Grasslands dominated by warm season (C4 photosynthetic pathway) showed the greatest response to temperature while cool season (C3 photosynthetic pathway) dominated regions responded most strongly to CO_2 enrichment. Modeled NPP responses in northern latitudes compared favorably with experimental results from the Prairie Heating and CO_2 Enrichment PHACE experiments and to NPP estimates derived from the Moderate Resolution Imaging Spectroradiometer (MODIS). Collectively, these results point towards significant and asymmetric changes in NPP for U.S. drylands that will require management tailored to regional and local projections. Effects of changes in NPP will vary regionally, but overall, increases should be positive from an economic perspective unless they manifest as invasive species. Increasingly, research suggests potential for increased abundance of invasive annual species. Presently, the resistance to invasion on many of our rangelands is quite low given abiotic factors and land use history. This resistance may decrease through time as soil temperature and moisture regimes become more favorable for establishment of invasive species.

Climate Change and Invasive Grasses. Lisa J. Rew*; Montana State University, Bozeman, MT (172)

Global climate change is effecting the distribution of plant species globally. Mean annual temperatures are increasing throughout the West, particularly at higher elevations, and this increase is set to continue. CO_2 is also increasing, and remained above 400 ppm for the first time in 2016. Annual precipitation shows less of a long-term pattern, with ocean-atmospheric oscillations (e.g. La Nina/El Nino, Pacific Decadal Oscillation) causing shorter-term variability. Precipitation is generally predicted to remain the same or become drier, with more variability and changes in the form of the precipitation at higher elevations and latitudes. These climate changes correlate with other changes including increases in fire frequency, land-use etc., all of which alter the distribution of plant species. Many invasive plant species are set to benefit from global change. I will discuss how the distribution of annual grasses is predicted to change in the West, what we know about community response to annual grasses under a changing climate, and how this should influence management practices.

Climate Change, Extreme Events and Invasion. David Clements*; Trinity Western University, Langley, BC (173)

Hitherto most research on climate change and invasive plants has focused on the influence of either climate warming or increased CO_2 levels on invasive plants. However, extreme climate events are also an important consequence of rising greenhouse gas levels. With increased average temperatures, increased frequency of warm temperature extremes are expected, along with increased drought frequency and severity. Yet greater variability in rainfall is also predicted due to the 7% increase in water holding capacity for every 1° C rise in temperature. This increase in atmospheric water vapor will trigger more severe storms. Whether increases in frequency and severity of extreme climate events enhance invasion success will depend on the severity of the event, the nature of the invaded community, and adaptability of the invaders. I will review predicted responses of invasive plants to three major extreme weather categories: droughts, floods and storms. Cheatgrass (*Bromus tectorum*) thrives under more arid conditions (with frequent droughts) that are anticipated to occur in the Pacific Northwest because it primarily needs spring precipitation, and senesces in the summer. Rainfall extremes may cause fluctuating water levels in wetlands. Non-native common reed (*Phragmites australis*) thrives with fluctuating water levels because it needs a temporary dry shoreline for seeds to germinate, and reproduction by seed may improve long-term adaptability via genetic differentiation. Some of the most powerful storms predicted with climate change are anticipated to impact invaded communities in the tropics, e.g., invasive woody plant invaders that take advantage of disturbance caused by violent storms. However, these storms may also migrate north, such as the case of Tropical Storm Irene striking Vermont in 2011, resulting in invasion of disturbed areas by fragments of Japanese knotweed (*Fallopia japonica*). Although there is a growing number of examples of predicted effects of extreme climatic events on invasive plants, more systematic research is urgently needed because many of the effects are much more immediate than the anticipated changes due to global warming. Such research can be used to develop proactive strategies to cope with the "new normal" of more extreme weather.

Biological Control and Climate Change. Sharlene Sing*; USFS, Bozeman, MT (174)

Predicting how climate change might affect classical biological control of weeds must begin by considering how elevated atmospheric CO_2 and deviations from typical temperature and precipitation patterns may separately and interactively influence the biology, ecology and interactions of invasive plants and non-native biological control agents. Environmental variables and biotic interactions correlated with successful vs. unsuccessful invasion (or establishment), both of invasive weeds and intentionally introduced classical biological control agents, remain at best broadly defined. Range expansion, for example, is frequently predicted for non-native plants and insects, but may ignore environmental requirements (e.g., day length; obligatory period of senescence/diapause at cold temperatures) that ultimately restrict species-specific distributions. Elevated winter temperatures will undoubtedly affect demographic factors such as overwinter mortality and voltinism that currently constrain agent population increase, especially where climate matching is imperfect. However, lasting population and even species level impacts of environmental conditions during the transitional period between 'normal' and persistent climate change conditions must also be considered. For example, season-long snow cover can provide a buffered and thermally stable microclimate for overwintering insects, but during such transitional periods, lethal freezing temperatures may still occur but snow cover will likely be absent, scant or ephemeral. Climate mediated changes in plant phenology and physiology have the potential to enhance, decrease or obviate their acceptance and utility for agent food and reproductive purposes. A mechanistic understanding of how climate change may impact invasive plants, their biocontrol agents, and target weed-agent interactions is therefore essential to forecasting the success and limitations of weed biological control in the future.

Agricultural Professionals' Perceptions about Climate Change. Irene Grimberg*; Montana State University, Bozeman, MT (175)

A survey focused on observations and perceptions of climate change was deployed in the state of Montana during Spring and Summer of 2016. Four hundred and eighty three agricultural stakeholders state-wide completed the survey, including conventional and organic farmers, ranchers, extension agents, and researchers. Stakeholders from all Montana's agricultural production regions participated in the survey. The survey was organized in four sections addressing observations of changes and variability of environmental factors, observations of changes in agricultural production, attitudes and concerns about the impact of climate change on agriculture, and current practices and preferred programs to mitigate the impact of climate change. Survey responses were analyzed by demographic parameters, including stakeholder group, agricultural region, age, income, and political view. Preliminary results show no significant difference among demographic groups, such that they all observed moderate or large changes in temperature, precipitation, number of warm days, daytime temperature, length of growing seasons, availability of water supplies, and pests. Stakeholders' attitudes and concerns, and preferred mitigation programs vary depending on stakeholder group, agricultural production region, or participant's political view. All in all, this state-wide evaluation indicates that agricultural stakeholders in Montana are aware of environmental and agricultural production changes due to climate, and that main differences regarding attitudes towards the observed changes and preference of mitigation programs are associated to stakeholder activity and location. Results from this survey could effectively inform Extension and Outreach programs on climate change to strategically target different stakeholder groups of different regions in Montana.

DISCUSSION SESSIONS

Project 1 Discussion Session: Weeds of Range and Natural Areas

Moderator: Tim Harrington, PNW Research, USDA Forest Service, Olympia, WA

Topic: *Weed Competition Models and Plant Community Responses – How to account for site conditions when predicting impacts of invasive plants?*

Discussion

For example, if we take soils into consideration could we reduce our management effort because Scotch broom is less of a long term threat?

Look at gradient studies – helpful for managers to focus resources on areas with greatest expansion threat.

We don't often know what the limiting factor(s) is/are….

It doesn't take much cover of an aggressive competitor to impact desirable species.

Helpful to look at "extremes" or the edge/outlier patches to help ID some important factors. Sometimes the state of the infestation, like yellow starthistle, influences invasion (e.g. propagule pressure).

Basic biology is important as well as competitive interactions – "best growth" is not always dominant at that kind of site, depending upon other factors.

Soils are important!

Site condition can change over time due to management, state & transition, etc.

Ecological Site Description – NRCE effort, perhaps more promise than being realized, but still need more information. It could make data "portable" from one site to the next.

Dynamic ecosystems don't fit linear statistics.

Plants themselves are changing – hybridization, polyploidy, etc.

Novel associations with fungi, viruses, etc. can confer new adaptive abilities, invade new systems

Weeds are a symptom of a problem and we need to discover the problem.

Nominations of a new Chair-Elect:

Derek Sebastian was nominated and elected as the new Chair-Elect for the Range and Natural Areas Project of WSWS.

<u>Chair 2017:</u>

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Chair-Elect 2017:
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sbautista@fs.fed.us

Chair-Elect 2018:
Derek Sebastian, Bayer, Fort Collins, CO
derek.sebastien@bayer.com

Attendees:

Name	Affiliation	E-mail
Tim Harrington	USFS PNW Research Station	tharrington@fs.fed.us
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Vanelle Peterson	Dow AgroSciences	vfpeterson@dow.com
Gina Ramos	USDI – BLM	gramos@blm.gov

Kathrin LeQuia	Univ. of Idaho	klequia@uidaho.edu
Jeff Mosley	MT State Univ	jmosley@montana.edu
D. Chad Cummings	Dow AgroSciences	dccummings@dow.com
Brian A. Mealor	Univ. of Wyoming	bamealore@uwyo.edu
Clay Wood	Univ. of Wyoming	cwood13@uwyo.edu
Shawna Bautista	USFS – Region 6	sbautista@fs.fed.us

Project 2 Discussion Section: Weeds of Horticultural Crops

Moderator: Pamela J.S. Hutchinson, University of Idaho,

Topic: *Business Meetinga and Potential Discussion of Topics For 2018*

Twelve interesting and engaging papers including three graduate student contest papers were presented Tuesday afternoon March 14, 2017. A business meeting followed the presentations. Marcello Moretti, Oregon State University, was nominated to become the new Chair Elect, no other nominations followed. The vote for Moretti was unanimous in the affirmative.

Following the vote, a brief discussion took place as to possible Weeds of Horticultural Crops Section Discussion topics for 2018. A few ideas were put forth. All present were interested in exploring the impact of drought on weed management in horticultural crops for the 2018 Discussion.

Chair 2017:
Pam Hutchinson, Aberdeen Research & Extension Center, 1693 S 2700 W, Aberdeen, ID 83210.
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Chair Elect 2017:
Andy Robinson, North Dakota State University/University of Minnesota, Loftsgard Hall, 4746, PO Box 6050, Fargo ND 58108
aprobins@umn.edu

Chair Elect 2018:
Marcello Moretti, Orgeon State University, Corvallis, OR 97331
marcelo.moretti@oregonstate.edu

Attendees:

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Brent Beutler	University of Idaho	bbeutler@uidaho.edu
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Pamela J.S. Hutchinson	University of Idaho	phutch@uidaho.edu
Tim Miller	Washington State University	twmiller@wsu.edu
Marcelo Moretti	Oregon State University	marcelo.moretti@oregonstate.edu
Ed Peachy	Oregon State University	Ed.Peachy@oregonstate.edu
Kai Umeda	University of Arizona	kumeda@cars.arizona.edu

Project 3 Discussion Section: Weeds of Agronomic Crops

Moderator: Caleb Dalley, NDSU, Hettinger, ND

Topic: *Herbicide Drift and Nozzle Seletion for Weed Control Research in Agronomic Crops.*

The discussion session opened with chair Caleb Dalley giving a brief presentation on nozzles and current restrictions to nozzle uses being written into herbicide labels. Discussion focused primarily on the specifications on which nozzles could be used in the new dicamba and 2,4-D resistant soybeans when using the herbicides Engenia, XtendiMax, and Enlist Duo. Nozzles currently approved were discussed as well as the speed and pressure requirements for these nozzles. A discussion was made of what nozzles should be used for research as it relates to drift and to be in compliance with labelling. It was mentioned that with most of the approved nozzles, the application volume would be too great to be used in hand-boom applications or in small tractor-mounted sprayers. It was also discussed on whether the XR nozzle should continue to be used in weed science research trials. Chris Mayo commented that he had approval for use of the TTI 110015 nozzle for research applications. Greg Dahl commented that he typically uses AIXR nozzles for research applications. Others also mentioned use of AIXR and TTI nozzles. It was also mentioned that there would be a symposium at the WSSA meeting next year that discusses nozzle selection and drift. Without further comments the discussion session was closed.

Minutes for the business meeting:
-Caleb Dalley calls the business meeting to order and opens nominations for chair-elect
-Caleb Dalley nominates Vipan Kumar as chair-elect for 2018
-Seeing no other nominations Caleb Dalley moves to elect Vipan Kumar chair-elect
-Greg Donald seconds the motion to elect Vipan Kumar chair-elect
-Vipan Kumar is unanimously elected chair-elect by voice vote
-Caleb Dalley moves to adjourn business meeting

<u>Chair 2017:</u>
Caleb Dalley, North Dakoda State University, PO Box 1377, Hettinger, ND 58639
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<u>Chair-elect 2017:</u>
Rand Merchant, BASF, Greeley, CO
Rand.merchant@basf.com

<u>Chair-elect 2018:</u>
Vipan Kumar, Montana State University, Huntley, MT
vipan.kumar@montana.edu

Attendees:

Name	Affiliation
Greg Endres	North Dakota State University
Caleb Dalley	North Dakota State University
Tom Larsen	AMVAC
Jim Daniel	Daniel Ag Consultin
Ray Pigati	Winfield United
Greg Dahl	Winfield United
Tye Shauk	BASF
Jim Vandercoevering	BASF
Kyle Keller	BASF
Rand Merchant	BASF
Kyle Roerig	Oregon State University
Dean Maneska	Bayer Crop Sciences
Ed Davis	Montana State University
Andrew Fillmore	West Central
Kyle Effertz	Vision Research Park
Ryan Peterson	Vision Research Park
John Frihauf	BASF
Alan Helm	Gowan
Lloyd Haderlie	Agraserv
Bill Cobb	Cobb Consulting
Curtis Rainbolt	BASF
Blake Kerbs	Gowan Company
Gary Willoughby	North Dakota State University
Carl Coburn	University of Wyoming
Corby Jensen	Monsanto
Ryan Rapp	Monsanto

Katie Martin	UC Davis
Phil Westra	Colorado State University
Nelson Geary	North Dakota State University
Cody Lee	North Dakota State University
Patti Prasifka	Dow AgroSciences
Jack Pieper	Vision Research Park
Paul Johnson	South Dakota State University
Jeff Krumm	DuPont
Ken Calson	DuPont
Marty Schraer	Syngenta
Mark Wruke	Bayer Crop Sciences
Chris Mayo	Monsanto
Brett Miller	Syngenta
John Roncoroni	Universty of California
Don Morishita	University of Idaho

Project 4 Discussion Section: Teaching and Technology Transfer

Moderator: Jenna Meeks, University of Wyoming, Lingle, WY

Topic: *Open Access Publishing for the Open-Minded*

Discussion notes:

- What is it?: No fees to look at article otherwise $40-50 a year
- Personal experiences:
    - Larry: Good teaser to pique interest, could act more as a progress report, doesn't have to be a peer reviewed journal (blog?), can works better on a tighter budget
    - Carl: PLOSonE is one option and allows for author updates and comments
    - Variable costs to publish from free to >$4,000
    - Concern that non-peer reviewed can lead to missed egregious errors
        - Predatory journals can be a large portion of online publishers
        - Must look into any journal submitted to
- Profits are greatest in traditional publishers and least in open-access publishers
    - Some traditional journals run by societies and are an important revenue source
- Library fees to subscriptions very high
- Open access makes it less expensive to publish by avoiding print versions
- Tax dollars pay for research
    - Acceptable that public does not have access to research they funded?
- Perceptions of open access
    - Pre-tenured faculty feel pressured to pursue higher impact journals which are often traditional
    - Other metrics of impact that consider utilization of information by the public (e.g., social media) can be provided to show impact (e.g., alt metric)
        - Most important for extension faculty
    - Traditional publications often have an open access option
        - Also more expensive which can be a challenge for pre-tenured faculty
- There are resources to identify legitimate open access journals

Chair 2017:
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Chair-elect 2017:
Dan Tekiela, University of Wyoming, Department of Plant Sciences (Dept. 3354), 1000 E. University Ave., Laramie, WY 82071
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<u>Chair-elect 2018:</u>
Kirk Howatt, North Dakota State University, Department of Plant Sciences (Dept. 3354), 1000 E. University Ave., Laramie, WY 82071
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<u>Attendees:</u>

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John Spring	Washington State University	john.spring@wsu.edu
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Larry Lass	Retired	larry.lass.ui@gmail.com
Carl Coburn	University of Wyoming	ccoburn2@uwyo.edu

Project 5 Discussion Session: Basic Biology and Ecology

Moderator: Brad Hanson, University of California, Davis, CA

Topic: *Moving Beyond Herbicide Resistance: What are the basic biology and ecology research needs in the Western US?*

Section Chair Brad Hanson facilitated the discussion and co-chair Nevin Lawrence compiled the following brief notes on the discussion. The last item of business was to elect a co-chair for this session at the 2018 meeting. Lynn Sosnoskie from Washington State University was nominated and elected to the position; she will co-chair the session in Anaheim, California in 2018 and will chair in Denver, CO in 2019.

The discussion was quite free flowing and included several diverse subjects. Clearly, there are numerous research opportunities and challenges, other than herbicide resistance, that need to be addressed by Weed Science. Major topics included:

- Establishing one or more weed model species for genetic studies and coordinating time and resources to study weed genetics.
- Weed scientists can now begin to study specific traits at the gene level, often times relying on model species gene resources rather than sequencing weedy plants.
- We know very little about the mechanisms of crop yield loss due to weed competition. The influence of root signaling and light quality on plant competitions are two areas where more research is needed.
- Weed interactions within the rhizosphere, and the rhizosphere in general, is an under-researched area of study.
- Better understanding seed germination biology, and the capacity of weeds to adapt the timing of germination, may help improve management and our understanding of weed adaption to climate change.
- The long-term impacts of harvest weed-seed destruction on the seed bank are not well understood.
- Pest management tends to focus on a single discipline (Pathology, Weed Science, and Entomology) at a time rather than considering the whole pest environment.

Actionable items that may be topics of future discussion sessions, meetings, or symposiums include:

- Hosting a seminar on emerging genetic technologies.
- Establishing a database of weed genetic information similar to other online gene databases.
- Pooling efforts to study weed genetics across universities.

Discussion points ordered by time are as follows.

1. The first topic discussed was that of weed germination biology and ecology. Several research questions were asked including: how does fall tillage or herbicide applications impact weed germination in the spring, what is the natural variation of particular weed species with respect to the timing of germination, and what is the capacity of weeds to change the timing of germination to adapt to management? Side discussions relating to weed seed germination included:

    a. Weed Science often focuses on weed adaption to management, often herbicides, but can we also focus on climate change and other evolutionary pressures and explore the capacity of weeds to change germination patterns or other traits in response to climate change?

    b. The weed spectrum in some regions has shifted as no-till has become more prominent, particularly in respect to "roadside" weeds moving into agronomic fields.

2. From germination biology, the discussion progressed to the topic of understanding germination at the genetic level. We are now able to explain the mechanism of weed germination at the gene level. Investigating weed genetics at the gene level doesn't necessarily require high level sequencing of weed species as some weed species are related to model species or highly studied crop species. Genes of interest may be conserved across genera to allow the development of markers. Furthermore, the standards for annotating a gene are very high and we can be confident of relating weed species of interest to reference genes from related of plants. Side topic included:

    a. Understanding the genetic controls of traits of interest, such as metabolism, will help our understanding of weed response to climate change for example.

    b. The point was made that we will still need to sequence some weed species to better understand the biology of weeds. With limited resources we should combine efforts and focus just on a few key weeds. If we were to focus on a few key weeds, which ones should we choose? Any weed will come with "baggage" as even related species can be quite different genetically (for example the ploidy level or the repetitiveness of the genome). Two species that were mentioned as possible candidates for "model weed species" were kochia (*Kochia scoparia*) and downy brome (*Bromus tectorum*).

    c. As weed genomes are investigated more, should there be an online repository for genetic information similar to other genome projects? The major issue with creating such a database would be cost. If a project was started access may need to be limited to those who collaborate on the project. Furthermore, private industry sponsorship may be necessary to help pay for such a project.

3. To refocus the discussion the question was asked what is going to be the defining theme of Weed Science in 10 to 50 years, will Weed Science still be focused mainly on herbicide-resistance?

a. The point was raised that very little is known about the mechanisms of yield loss in crops as considerable yield loss can occur without any competition for resources. Light quality and root signaling were brought up as two potential avenues for further research.

b. The discussion then refocused to the subject of rhizosphere biology and ecology and specifically how the rhizosphere may influence the weed spectrum. The following points were raised in the ensuing discussion.

   i. Can we manipulate or tweak the phytobioms or rhizosphere and what impact does that management of the soil have on weed species?

   ii. Can we investigate soil health at smaller scales, such as root signaling between plant species?

   iii. Colorado State University, and potentially other universities, are investing into soil ecology and biology at a fine scale. Is there a place of weed science within this discipline?

4. A point next raised that we don't know what allows a plant to adapt to stress and become weedy. Further, the role of polyploidy on plant or weed fitness is relatively unknown. Specifically does certain genome of polyploidy weeds contribute more to fitness than others? Data does indicate that herbicide-resistance traits on particular genomes can contribute more to the ability of plant to resist herbicides.

5. It was pointed out that the discussion had so far focused on weeds in agronomic systems. It was asked: What are the major challenges to basic biology and ecology in range settings? Changing plant distribution and new invasions by weeds due to climate change was the consensus answer.

6. Two presentations were given about post-harvest weed seed destruction at the WSWS and the popularity of the practice is increasing. Has research previously addressed how much seed destruction is necessary to decreases the seed bank in the long-term? Given the potentially millions of seeds contributed to the seed bank each season, even a high level of control may be inadequate.

7. Should we be discussing more about Crisper, RNAi, gene silencing, and other emerging genetic technologies? These emerging technologies, and their applications in Weed Science, could be a topic of a future symposium.

8. We don't discuss much about weeds in whole pest environments. When a single pest or type of pest is targeted there can be contradictory pest control recommendations.

   a. Weed Management is rarely studied from the standpoint of broad ecological issues such as water management, pollinator health, or soil biota communities.

   b. Do we need to take back the notion of IPM, by including all pests rather than just IPM from separate disciplines? Such an approach may unify pest management recommendations and simply the adoption of integrated approaches.

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Chair-elect (Co-chair) 2017:
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Chair-elect 2018:
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Attendees

Name	Affiliation
Ian Burke	Washington
John Spring	Washington
Lynn Sosnoskie	Washington
Robert Norris	California
John Roncoroni	California
Caleb Squires	Washington
Pete Berry	Oregon
Andrew Kniss	Wyoming
Brian Jenks	North Dakota
Phil Westra	Colorado
Fabian Menalled	Montana
Ryan Rapp	South Dakota
Phil Stahlman	Kansas
Jill Schroeder	Washington DC
Joan Campbell	Idaho
Andrew Swain	Utah

Discussion Section: Education and Regulatory

Moderator: Sandra McDonald, Mountain West PEST, CO

Topic: *Risk Communication*

No report available

WESTERN SOCIETY OF WEED SCIENCE NET WORTH REPORT

April 1, 2016 through March 31, 2017

ASSETS	
Cash and Bank Accounts	
American Heritage Checking	$70,951.15
American Heritage Money Market	$51,076.50
CD#3	$25,000.00
CD#4	$25,000.00
CD#5	$25,000.00
CD#6	$25,000.00
CD#7	$25,000.00
TOTAL Cash and Bank Accounts	$247,027.65
Other Assets	
Asset (Weeds of the West unsold inventory)	$8,347.54
TOTAL Other Assets	$8,347.54
Investments	
RBC Dain Rauscher Acnt	$195,454.10
TOTAL Investments	$195,454.10
TOTAL ASSETS	$450,829.29
OVERALL TOTAL	$450,829.29

WSWS CASH FLOW REPORT

April 1, 2016 through March 31, 2017

INFLOWS	
Annual Meeting Income	108,481.23
California Weeds Books (book sales)	100.21
DVD Weed ID (book sales)	35
Interest Inc	556.26
Renewal Membership	1,080.00
Rita Beard Endowment	60
Royalty For Proceedings Or RPR	840
Student Travel Account	1,568.50
Sustaining Member Dues	15,500.00
Weed Control In Natural Areas (book sales)	364
Weeds Of The West (book sales)	29,240.12
TOTAL INFLOWS	**157,825.32**
OUTFLOWS	
Annual Meeting Expense	63,276.41
Bank Charge	15
CAST Annual Dues	1,500.00
Director Of Science Policy	5,001.00
Insurance	500
Merchant Account	5,411.92
Service Contract	26,820.00
Stipend	1,500.00
Supplies	483.02
Tax	184
Tax Preparation	460.33
Travel To IMI	409.6
Travel To Summer Meeting	4,172.54
Travel To WSWS Meeting	2,796.26
Web Site Host	4,000.00
TOTAL OUTFLOWS	**116,530.08**
OVERALL TOTAL	**41,295.24**

WSWS 2017 FELLOW AWARDS

Fellows of the Society are members who have given meritorious service in weed science, and who are elected by two-thirds majority of the Board of Directors.

Dr. Ralph Whitesides

Ralph Whitesides received his BS in Agronomy/Botany from Utah State University in 1974, his MS (1978) and his PhD (1979) in Crop Science/Weed Science from Oregon State University. He was a faculty member at Oregon State University, Washington State University, and Utah State University. Ralph has worked extensively in Weed Science Education as an Extension Specialist and in university teaching assignments. University courses included: World Food Crops, Field Crops, University Survival, Forage Production & Pasture Ecology, Weed Management, Weed Biology and Control, and a variety of topics as Special Problems. He has taught Extension Programs in Utah and many other states, Thailand, and China. He has conducted invasive plant management training for the US Forest Service, US Fish and Wildlife Service, USDA Farm Services Agency, and the Utah Weed Control Association. Ralph has been an active member of the WSWS for 24 years as a participant and presenter and has served as member-at-large, Chair of the Education and Regulatory Section, on the Ethics Committee, Weeds of the West marketing committee, Necrology Committee, Student Paper Judging Committee, and as Emcee of the WSWS Awards Banquet. Ralph was recognized in 2008 with the USDA Certificate of Appreciation from FSA, in 2010 by Utah State University's College of Agriculture as Teacher of the Year, in 2014 by the Utah Weed Control Association with the Weed Supervisor Appreciation Award, and in 2014 with the Utah State University E. G. Peterson Extension Award. Ralph has also served WSSA as an Executive Board Member (Constitution and Operating Procedures) from 2005-2011, Utah State Weed Board 2005-2016, and on the Executive Committee of the Utah Weed Control Association 2002-2016. He retired from Utah State University as Professor and Extension Weed Specialist in July 2016. Ralph recognizes many colleagues and friends for their contributions to his career, with special thanks to Dr. Arnold P. Appleby. He considers his greatest accomplishment in life to be his relationship with his wife and children, none of whom pursued a career in Weed Science, but all of whom have supported Ralph in his love for undesirable vegetation management.

Dr. Ed Peachey

Dr. Ed Peachey is from a small farming community in central Pennsylvania. After leaving the farm for greener pastures in Oregon, it took a few years working in the building industry before he rediscovered his interest in agriculture and enrolled at Oregon State University. There he worked as an undergraduate for weed scientists Dr. Appleby and Larry Burrill. The project he was assigned was time-lapse photography of herbicide effects on weeds. The hook was set, and from that point on, weed science was the focus of his career. He continued studies at OSU and received a BS degree in Horticulture in 1987. After a 3-year term in Bangladesh with a non-governmental rural development organization, he returned to Oregon and completed an MS Degree in Horticulture in 1993 and began a PhD in Crop and Soil Science in 2001, completing in 2004. Ed first attended WSWS in 1993 and has been an active member since, missing one meeting in 24 years. He has served in several capacities including Research Section Chair and as a member of the Board of Directors. He also has chaired the Weeds in Horticultural Crops section twice, and the Alternative Methods of Weed Control section.

Dr. Peachey is currently serving (since 2015) as regional weed and pest management specialist in the Willamette Valley of Western Oregon. His primary focus is processed vegetables, but he also evaluates weed and other pest management technologies in fresh market vegetables and seed crops. From 2008 to 2014, he worked to develop chemical and biological controls for perennial weeds such as field bindweed in caneberries, blueberries, strawberries and hazelnuts, in addition to work in vegetable crops. In 2008, he also became the managing editor of the PNW Weed Management Handbook. He has worked with scientists in the PNW and across the country to develop sustainable and cost effective weed management options in conventional and organic crops, and worked closely with IR-4 (USDA) to bring several crucial registrations to growers of specialty crops, including snap beans, processing squash, vegetable crops grown for seed, rhubarb, blueberries and caneberries. Dr. Peachey received the Weed Worker of the Year award from Oregon Society of Weed Science in 2003, and the professional Service Award from WSWS in 2006.

WSWS 2017 Honorary Member

This award was not conferred in 2017

WSWS 2017 OUTSTANDING WEED SCIENTIST – Erik Lehnoff

The Outstanding Weed Scientist, Early Career was awarded to Erik Lehnoff

Erik Lehnhoff is an Assistant Professor at New Mexico State University, and prior to joining New Mexico State in 2015 he was an Assistant Research Professor at Montana State University. Erik's research has two main focus areas: (1) ecology and management of rangeland and riparian invasive species and (2) improving sustainable weed management for traditional and specialty crops. Within the rangeland context his research examines the causes and consequences of invasion, and in particular seeks a greater understanding of impacts at different trophic levels, from mycorrhizae to plants to pollinators. Erik's recent research is evaluating plant invasions through the lens of climate change; assessing how increased temperatures and/or altered precipitation may affect invasion and interactions among plants. Other research aims to integrate biological control (insects or livestock) with herbicide to improve weed management and reduce off-target impacts. With respect to agronomic weeds, Erik is addressing how cover crops affect weeds directly through competition/suppression and indirectly through changes to soil physical, chemical and biological properties. His research has contributed to 22 peer reviewed journal articles and 26 presentations at regional, national and international meetings. Erik is also committed to undergraduate and graduate instruction and currently teaches courses on integrated pest management and plant ecology, as well as a graduate seminar. He has also taught at the Southwest Noxious Weed Short Course and pesticide applicator workshops. In addition to teaching he is active in mentoring both undergraduate and graduate students, working with numerous undergraduates and serving on ten graduate committees in the last two years.

WSWS 2017 WEED MANAGER AWARD

This award was not conferred in 2017

WSWS 2017 PROFESSIONAL STAFF AWARD

This award was not conferred in 2017

WSWS 2017 PRESIDENTIAL AWARD OF MERIT – Phil Stahlman

Phil Stahlman received the WSWS Presidential Award of Merit from Kirk Howatt at the 2017 annual meeting in Coeur d'Alene, Idaho.

WSWS 2017 STUDENT SCHOLARSHIP RECIPIENTS



The awards committee received three graduate applications for the Elena Sanchez Memorial WSWS Scholarship. All three applicants were outstanding and were supported by impressive research papers presented at the Coeur d'Alene meeting. The recipients of the Elena Sanchez Memorial Scholarship were Neeta Soni (CSU), Mariano Galla (UC-Davis) and Caio Brunharo (UC-Davis). A big thanks to their graduate advisors for bringing along such great talent for the future of weed science. Winners pictured with WSWS President Kirk Howatt.

WSWS 2017 STUDENT PAPER AND POSTER AWARDS

The 2017 WSWS Student Paper Contest included 17 poster presentations and 19 oral presentations. Students who participated in the contest are to be commended for their excellent presentations. As is customary, the students with poster and oral presentations were each divided into different groups. According to the rules of the student paper contest, the number of winning places in different sections varied from one to two, depending on the number of students in each group.

Students in the oral presentations were divided into five groups each representing one section, Aquatics, Basic Biology and Ecology, Weed of Agronomic Crops, Weeds of Horticultural Crops, and Weeds of Range and Natural Areas.

Oral Paper Contest Awards – Aquatics

In the Aquatics section, the first place oral presentation winner was Erika J. Haug, North Carolina State University. Her winning presentation was titled *Procellacor: concentration exposure time trials.* Winner pictured with WSWS President Kirk Howatt.

Oral Paper Contest Awards – Weeds of Range and Natrual Areas

First place winner in the Weeds of Range and Natural Areas oral presentation section was Tara Burke, Washington State University, and her presentation was titled *Vernalization Effects on the Translocation of Aminopyralid and Clopyralid in Rush Skeletonweed* (*Chondrilla junceaL.*). Winner pictured with WSWS President Kirk Howatt.

Oral Paper Contest Awards – Weeds of Horticultural Crops

The first place oral presentation winner in the Weed of Horticultural Crops section was Caio Augusto Brunharo, UC Davis, and his presentation was titled *Evidences for Vacuolar Sequestration as Mechanism of Resistance to Paraquat in a Population of Italian Ryegrass from California*. Winner pictured with WSWS President Kirk Howatt.

Oral Paper Contest Awards – Weeds of Agronomic Crops

The first place winner in the Weeds of Agronomic Crops oral presentation section was Charlemagne A. Lim of Montana State University. His presentation was titled *Survival, Growth, and Reproductive Fitness of Dicamba-Resistant Kochia in the Presence of Dicamba.* Second place winner was Curtis M. Hildebrandt, Colorado State University, and his presentation was titled *Viability Assessment of Mutagenesis-derived ACCase Resistant Wheat Lines as a New System for Control of Winter Annual Grasses.* Winners pictured with WSWS President Kirk Howatt.

Oral Paper Contest Awards – Basic Biology and Ecology

The first place winner in the Basic Biology and Ecology section was Carl W. Coburn, University of Wyoming, and his paper was titled *Influence of Soil Type and Growing Environment on the Selectivity Index in Herbicide Resistance Studies.* Second place winner was Neeta Soni, Colorado State University, and her presentation was titled *Integrated Weed Management of Winter Annual Grasses in Wheat using Harvest Weed Seed Control.* Winners pictured with WSWS President Kirk Howatt.

Poster Presentation Awards – Undergraduate Poster

The undergraduate poster presentation winner was Grace K. Ogden, Oklahoma State University. Her winning poster was titled *Pyroxasulfone Weed Management Systems in Oklahoma Winter Wheat.* Winner pictured with WSWS President Kirk Howatt.

Poster Presentation Awards – Aquatics, Weeds of Horticultural Crops and Basic Biology and Ecology

Graduate student poster presentations in the Aquatics, Weeds of Horticultural Crops, and Basic Biology and Ecology projects had two winners. First place was Mirella Ortiz from Colorado State University. Her winning poster was titled *Absorption Rates of 2,4-D Butoxyethyl Ester and 2,4-D Amine by Eurasian Watermilfoil.* Second place winner in the same group was Albert Adjesiwor, University of Wyoming. His poster was titled *Kin Recognition in Beta vulgaris.* Winners pictured with WSWS President Kirk Howatt.

Poster Presentation Awards – Weeds of Agronomic Crops

The other group of graduate student posters was represented in the Weeds of Agronomic Crops project. First place winner was Tara Burke from Washington State University and her poster was titled *Russian Thistle* (*Salsola tragusL.*) *and Lambsquarter* (*Chenopodium album L.*) *Control in Sweet Corn.* Second place winner was Clint W. Beiermann, University of Nebraska. His poster was titled *Integrating Crop Rotation and Herbicide Programs to Control Kochia Prior to Sugarbeet in Western Nebraska.* Winners pictured with WSWS President Kirk Howatt.

WSWS 2017 ANNUAL MEETING NECROLOGY REPORT

Tribute to Rita Beard – -2016

Rita Beard, a luminary in the federal and private sector of the invasive species world, passed away in October at her home in Fort Collins, CO. Throughout her career, Rita advanced her vision of coordinating invasive species management on a national scope. By encouraging collaboration from the field to congressional levels, she effectively changed the way invasive species are managed in this country. In addition, she worked to make sure that all invasive species management decisions were based on the latest and best available research and technology, thus ensuring that management decisions were supported by science. Towards that end, Rita spearheaded the development of the original mapping standards for the North American Invasive Species Management Association (NAISMA), which unified management practices to help ensure consistent data collection.

Rita's academic background served her well: she received her bachelor's degree in Ecology and Biosystematics from the University of California at Berkeley, followed by two Master of Science degrees; in Range and Wildlife Science from Montana State University, and in Forest and Public Policy from Oregon State University. She began her career in the late 1970s as the Range Conservationist and Invasive Plant Specialist, with the U.S. Forest Service on the Townsend Ranger District in western Montana. During this time, Rita made history by preparing the first Environmental Impact Statement on invasive plants in the United States, pioneering the use of herbicides to control invasive plants in wilderness areas.

In April 2005, she joined the National Park Service (NPS) as the National Invasive Plant Management Program Coordinator. At NPS she supervised 18 Exotic Plant Management Teams (EPMTs) and guided the development of policies related to invasive plant management and prevention. She professionalized this program by raising the level of technical expertise through training for her staff, communicating the importance of invasive plant management to NPS leadership, and increased the amount of funding available for weed management.

Rita's depth of knowledge and experience made her an invaluable partner of the NPS Integrated Pest Management Program.

On the national level, Rita was an effective liaison for local weed management partners, federal and nonfederal agencies, Congress, and others in Washington, D.C., ensuring that management decisions were based on science and core natural resource values. She served on several Departmental committees, including the National Invasive Species Council and the Federal Interagency Committee for the Management of Noxious and Exotic Weeds promoting the practical application of weed science principles and practices for invasive plant management.

Rita retired from the NPS in 2013 and continued to provide training and technical expertise to her partners. In 2014, Rita received the Western Society of Weed Science's Distinguished

Achievement Award in the category of “Weed Manager” for her tireless efforts in advancing the cause of invasive plant management across the entire country.

We honor Rita Beard, who exemplified the qualities of a rare colleague and complete person: grace, kindness, composure, intelligence, fearlessness, poise, and to be deliberate, unassuming, truthful, and loving.

Obituary for RICHARD S. NIELSEN – 1924 - 2016

Richard S. Nielsen, passed on to eternal life on Friday, November 25, 2016, at age 92. Richard, or "Dick" as he was called, grew up in Denver, CO. After being discharged from the military in 1950, he married Clare, the love of his life. The couple lived in the bay area, Colorado, Arizona, and finally settled in Fresno, CA for 52 of their 66 years together.

Dick was educated at the University of Arizona, and became a respected agricultural researcher with American Cyanamid Company for most of his career. He enjoyed the outdoors in his work and play, and was an avid cyclist and skier.

In his retirement years, he enjoyed volunteering at Hope Lutheran Church and working in the woodshop at their retirement community at San Joaquin Gardens. He is survived by his wife Clare; daughter, Kristine Adams and family; son, David Nielsen and family; as well as his brother-in-law, James Canterbury; and sister-in-law, Inez Losness, and their families.

Obituary for AMY PETERS – 1966 – 2017

Amy was born on March 27, 1966 and passed away on Friday, March 3, 2017 at the age of 50. Amy was a resident of Myrtle Point, Oregon. Amy was an Emeritus Professor in Animal and Rangeland Sciences and served as an outstanding Rangeland/Livestock Extension faculty member in the Coos County area, Oregon. Amy passed away peacefully this morning, at home with loved ones after a brave eight year struggle with cancer. Amy truly embraced life and many of us were blessed by sharing time with her.

Obituary for DENNIS J. TONKS – 1960-2016

Denni J. Tonks, 55, of Kearney, MO, passed away, August 16, 2016, at his home, surrounded by his family. Dennis was born Oct. 7, 1960 in Driggs, ID. He grew up near the Tetons in Victor, ID and loved the outdoors, the mountains, cars, snowmobiling, and helping on friends’ farms. He married Shirlene Miller Tonks on 1985 in the Idaho Falls, ID.

Dennis experienced job opportunities in several different areas through the years along with being a very involved father to four boys. They started their marriage in Provo, UT where Dennis finished his bachelor degree in Agronomy at Brigham Young University. He continued on to complete his masters and they had their first son, Jacob. Dennis embarked on more education, getting his Ph.D. from Colorado State University in Fort Collins, Co in Weed Science and adding another son, Derek. From there they moved to American Falls, ID while Dennis completed his Post Doc work with both University of Idaho extension and Sandoz, where they had their 3rd son, Cameron. They lived in Sterling, Co for a few years and Davenport, WA for 7 years working in an extension position with Washington State University. Their 4th child didn't come for some time and then, surprise, a 4th son, Braden! Dennis' later years were spent in Iowa and for the last 5 years he has enjoyed working for ISK Biosciences in Kearney, MO as a field development representative.

Dennis enjoyed camping, fishing, shooting, cars and just hanging out with his boys, all along teaching them many skills in his quiet, yet strong manner. He's been their Hero by his example to them and his wife of diligence, perseverance, commitment and love that will be in their minds forever. He has been a lifelong member of the LDS church. He served an LDS mission to Houston Texas in 1980-1982. Dennis also served in many church positions as a teacher, leader and often involved with the youth. He fought his colon cancer battle like everything else; quietly, enduring much as he kept going at his job and continually providing for his family until just recently when his decline came quickly.

He was preceded in death by his father, Elmo Tonks. He is survived by his mother, Verna Hansen Tonks; his wife, Shirlene Miller Tonks; 4 boys: Jacob, Derek, Cameron, and Braden Tonks; 4 siblings: Jeanine Tonks Sagers (Brent); Marie Tonks Hone (Robert); Brian Tonks (Nancy); Shauna Tonks Burke (Blaire); 34 nieces and nephews.

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2016-2017 WSWS Standing and Ad Hoc Committees

Board contact/(year-rotating off)

Awards -*President*
Alan Helm, Chair (2017)
Roger Gast, Chair (2018)
Gustabo Sbatella (2019)

Fellows and Honorary Members - *Past President*
Jill Schroeder (2017)
Kassim al-Khatib, Chair (2018)
Bill Cobb (2019)

Finance - *Member at Large – Public Sector*
Jesse Richardson (2017)
Stephen Valenti, Chair (2018)
Josh Adkins (2019)

Herbicide Resistant Plants
Member at Large – Private Sector
Prashant Jha (2017)
Marie Jansieniuk, Chair (2018)
Joan Campbell (2019)
Tara Burke, Student Rep

Program - *President-Elect*
Monte Anderson, Chair (2017)
Prashant Jha (2017)
Brian Jenks (2017)

Publications - *President-Elect*
Monte Anderson, Chair
Bill McCloskey, Proceedings
Traci Rauch, Research Prog. Report
Carl Libbey, Newsletter Co-Editor
Phil Banks, Website Editor

Student Paper Judging - *President-Elect*
Ryan Rector (2017)
Joel Felix, Chair (2018)
Ryan Edwards (2019)

Legislative - *WSSA Representative*
Fred Raish (2017)
James Leary, Chair (2018)
Patti Prasifka (2019)
Lee Van Wychen, Ex-officio

Local Arrangements - *President-Elect*
Brian Schutte (2017)
Scott Cook, Chair (2018)
Travis Bean (2019)

Necrology - *Secretary*
Ralph Whitesides (2017)
Judit Barasso, Chair (2018)
John Frihauf (2019)

Nominations - *Past President*
Scott Nissen (2017)
Steve Eskelson, Chair (2018)
Ryan Rapp (2019)
Drew Lyon, Past-President

Poster - *President-Elect*
Kirk Sager (2017)
Jared Unverzagt, Chair (2018)
Alan Helm (2019)

Public Relations
Education & Regulatory Section Chair
Joan Campbell (2017)
Todd Neel (2017)
Lynn Sosnoskie, Chair (2018)
Travis Bean, Co-Chair (2018)
Kai Umeda (2019)
Pat Clay (2019)

Site Selection - *President*
Charlie Hicks (2017)
Joseph Yenish, Chair (2018)
Steve Eskelsen (2019)

Sustaining Membership - *Past President*
Wendell Rich (2017)
Craig Alford, Chair (2018)
Ryan Rector (2019)