PROCEEDINGS

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2019

PROCEEDINGS

OF

THE WESTERN SOCIETY OF WEED SCIENCE

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PAPERS PRESENTED AT THE ANNUAL MEETING

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PREFACE

The Proceedings contain the written abstracts of the papers and posters presented at the 2019 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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The Minutes of the Board of Directors meetings and the Business Meeting are available at the WSWS website.

Proceedings Editor: Carl Libbey

POSTER SESSION

Undergraduate Posters

Effect of Weed Presence on Sugarbeet Injury with Phenmedipham and Desmedipham. Jacob M. Asay*, Elizabeth G. Mosqueda, Albert T. Adjesiwor, Andrew Kniss; University of Wyoming, Laramie, WY (060)

Presence of weeds has been documented to reduce crop growth through light competition. It is uncertain how herbicides influence competition for light in crop-weed interactions. Greenhouse studies were conducted in 2017 and 2018 to evaluate the effects of weed presence along with the herbicides ethofumesate, phenmedipham, and desmedipham on sugarbeet (Beta vulgaris L.) foliar injury. In all studies, the weed was grown in separate containers from sugarbeet so there was no root interaction. Injury was quantified by measuring chlorophyll levels, visual injury estimations, and dry weight analysis. In experiment 1, weed presence reduced sugarbeet chlorophyll concentration ($P = 0.003$). A combination of ethofumesate, phenmedipham, and desmedipham also reduced sugarbeet chlorophyll concentration ($P = 0.02$). In experiment 2 there was no difference in sugarbeet chlorophyll concentration between the non-weedy and weedy treatment ($P = 0.72$). However, sugarbeet chlorophyll concentration was reduced with increasing rates of phenmedipham plus desmedipham ($P = 0.06$). In experiment 3, phenmedipham plus desmedipham had no significant impact on either sugarbeet chlorophyll concentration ($P = 0.736$) or dry weight ($P = 0.173$), but weed presence reduced sugarbeet chlorophyll concentration and dry weight ($P < 0.001$). Weed presence caused 19% reduction in sugarbeet dry weight. These results showed that potential phytotoxicity of phenmedipham plus desmedipham in sugarbeet could increase in weedy environments.

Evaluating Efficacy of Various Herbicides for Bulbous Bluegrass Control. Jordan L. Skovgard*[1], Brian A. Mealor[1], Beth Fowers[2]; [1]University of Wyoming, Laramie, WY, [2]University of Wyoming, Sheridan, WY (061)

Bulbous Bluegrass (Poa bulbosa L.) is a widespread, yet relatively unstudied, invasive cool-season grass that reproduces primarily via bulblets. Few herbicides are labeled for its management in rangelands, and limited research exists that evaluates best control methods. Our objective was to evaluate the efficacy of various herbicides in controlling bulbous bluegrass. We established two field studies in northeast Wyoming in May 2017 to evaluate 11 herbicides alone, and combined with glyphosate, for their impacts on bulbous bluegrass. We applied herbicide treatments to 3 x 9 meter plots as a split-plot randomized completely block design with four blocks at each site. Glyphosate (520 g ae·ha-1) was applied to 1/3 of each block following other herbicide applications. We collected posttreatment data 30 and 160 day after treatment (DAT). We recorded canopy cover by species in ¼ m2 quadrats at a density of 6 quadrats per 0.3 are. Additionally, we visually estimated the control (%) of bulbous bluegrass and the damage (%) to perennial grasses and forbs. Glyphosate reduced bulbous bluegrass canopy cover 30 DAT at both sites ($p<0.05$), but we did not observe a glyphosate by other herbicide interaction. Litter (dead plant matter) displayed main effects of herbicide and glyphosate 30 DAT. By 160 DAT (October), most herbicides had higher litter than the nontreated check ($p<0.05$) but we observed no meaningful differences in bulbous bluegrass cover among treatments. Data to be collected in spring 2019, after bulbous bluegrass is more actively growing, will reveal more substantial impacts of herbicide treatments.

Expressing an *Amaranthus palmeri* Cytochrome P450 Candidate Gene for 4-Hydroxyphenylpyruvate dioxygenase (HPPD) Inhibitor Resistance in Yeast. Crystal Sparks*[1], Anita Kuepper[2], Franck Dayan[1], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Bayer CropScience, Frankfurt am Main, Germany (062**)**

Palmer amaranth (*Amaranthus palmeri*) is an annual broadleaf weed, native to arid portions of the southwestern United States and northwestern Mexico. Over the past several decades Palmer amaranth has become a troublesome weed in cropping systems throughout the southeastern and midwestern regions of the US, as well as more recent introductions into Argentina and Brazil. Palmer amaranth is highly competitive and substantially reduces crop yield. In more recent decades, Palmer amaranth has evolved resistance to at least five different herbicide mechanisms of action. Understanding the mechanisms that confer herbicide resistance can aid in development of better management practices and innovative new technologies for growers. While some mechanisms of resistance in Palmer amaranth are known, metabolic resistance is increasing in frequency and the mechanistic basis is unknown. With herbicides that act as inhibitors of 4-hydroxyphenylpyruvate dioxygenase (HPPD), metabolic activity on the herbicide is suspected as a means of survival at treatments upwards of field application rates. Previous RNA-seq analysis of herbicide resistant Palmer amaranth identified candidate genes for metabolism of some HPPD inhibitors. These are cytochrome P450s, a class of enzymes known to metabolize xenobiotics in many species. Baker's yeast, *S. cerevisiae*, is a well-known model for expression of membrane proteins. Cloning the candidate genes into a yeast expression vector facilitates the analysis of the cytochrome P450 protein activity on molecules of HPPD inhibitor, with metabolites analyzed on LCMS. The results of this analysis can provide validation of candidate gene activity on herbicide molecules.

Impact of Cheatgrass Control on Pollinator-Friendly Flora: Comparison of Indaziflam Treated and Untreated Plots. Nicholas DiMascio*, Janet Hardin, Arathi H. Seshadri; Colorado State University, Fort Collins, CO (063)

Paper withdrawn

Invasive Mustard Management in Utah. Lauren B. Stanko*, Corey V. Ransom; Utah State University, Logan, UT (064)

There is increasing concern in Utah's rangelands over the spread of elongated mustard (*Brassica elongata*), an invasive perennial confined to northern regions of the state, and African mustard (*Brassica tournefortii*), an invasive annual located in the south. Separate studies were initiated to evaluate postemergence herbicides for elongated mustard control, and preemergence and postemergence herbicides for African mustard control. All studies were conducted on plots measuring 3 by 7 or 9 m arranged in a randomized complete block design with 4 replications. Two African mustard trials, were established in 2017 and 2018, in Hurricane, UT. Preemergence treatments were applied December 2017 and October 2018, while postemergence treatments were applied March 2018 and January 2019. The spring after treatment, all herbicides provided 100% control in the 2017 trial. Metsulfuron and a low rate of 2,4-D provided slightly less control in the 2018 trial. Imazapic alone and treatments with indaziflam had 100% control the second springafter treatment in the 2017 trial. Two elongated mustard trials were established; one near Weston, ID in 2016, another in Newton, UT in 2017. Postemergence herbicide applications were made at Weston in May 2016 and at Newton in June 2017. In the Weston trial, only chlorsulfuron and metsulfuron reduced elongated mustard density one year after treatment. In the Newton trial all treatments, except dicamba, reduced elongated mustard density compared to the untreated control. Overall, annual African mustard was easier to control than perennial elongated mustard. The African mustard results suggests potential for incorporation of indaziflam into management approaches for elongated mustard.

Assessing *Phragmites australis* Coverage with Regards to Land Management. Chris M. Jones*, Steve Young; Utah State University, Logan, UT (065)

Location and vegetation characteristics generally affect the rate of spread of invasive plants. The measurement of invasive plant spread at fine-scales using patches can help in understanding movement and the effects of management. In field studies conducted in the Platte River of Nebraska, we measured the spread of non-native common reed (*Phragmites australis*) during a four year period. We used transects to measure cover of vegetation dominated by *P. australis* in small patches ranging from 10 to 50 m at sites that varied in management (e.g., grazing, herbicides, and/or burning). Friedman's Chi-Square test was applied to each site to determine significant differences in proportions of *P. australis* cover across years. Following herbicide applications, *P. australis* cover declined dramatically, while grazing maintained consistently low cover. No management approach eliminated *P. australis*, which would suggest an integration of tools is most effective.

Evaluating Native Perennial Grass Tolerance to Indaziflam Treatments. Shannon L. Clark, Stephen R. Lunt*; Colorado State University, Fort Collins, CO (066)

Invasive winter annual grasses, such as *Bromus tectorum* (downy brome), currently occupy up to >22 million hectares in the western United States, with an estimated annual spread rate for *Bromus tectorum* of ~14%. The loss of ecological resilience, biodiversity, and deviation from historic fire regimes from these winter annual grasses have been well documented. Limited viable treatment options exist, but chemical control options with long-term residual soil activity has been stated as an important factor to native regeneration and recovery. Indaziflam, a new herbicide option for invasive winter annual grasses in non-grazed rangeland and natural areas, has been shown to provide long-term residual control of germinating cheatgrass while showing little to no effect on native perennial grass species production. Previous published research has shown no negative impacts from indaziflam treatments to desirable species abundance and biomass, although no published research has evaluated impacts to seed production and viability. A field trial was conducted at the Plants Material Center in Meeker, CO to assess tolerance of 14 desirable perennial grass species to the herbicide indaziflam. Herbicide applications of indaziflam (73 and 102 $g \cdot ai \cdot ha^{-1}$) were made to perennial grasses in August 2017. In August 2018 (1 YAT) vegetative biomass, seed production biomass, and seed viability data were collected to assess any herbicide impacts on the perennial grass species. There was no significant decrease in vegetative or seed production biomass across all 14 perennial grass species in plots treated with indaziflam at both rates compared to the control plots. This data provides critical tolerance information to aid land managers in understanding the effects of this new tool for invasive annual grass control on desirable perennial grasses.

Stressing Out: Young Seeding Recovery Patterns for Popular Restoration Species, *Elymus trachycaulus*. Cynthia S. Brown, Magda Garbowski, KaMele E. Sanchez*; Colorado State University, Fort Collins, CO (067)

This study assesses the recovery of root and coleoptile tissues in slender wheatgrass, *Elymus trachycaulus,* after young seedling exposure to stressors during a susceptible stage in plant development. Our key research question is: How do root and shoot growth vary among four popular cultivars of *E. trachycaulus* after exposure to drought, cold, and heat stressors at the post-germination but pre-emergence stage of a seedling's lifecycle? *E. trachycaulus* is a native self-pollinating perennial whose abundance, phenotypic plasticity, and popularity has led to its utilization in ecological restoration throughout Western North America. Germination requirements of seeds and stress physiology of mature *E. trachycaulus* plants have been studied, but we know very little about the characteristics of seedlings that have germinated but not yet emerged. During this transition period, the plant has broken its seed coat and the emerging radical and coleoptile tissues are vulnerable to desiccation, freezing, disease and other environmental stressors. Seedlings are defenseless to stressors during this stage, and mortality in this stage may be a key contributor to poor plant establishment in vegetation projects. For this study, seeds of four cultivars will be germinated and their root and shoot tissues will be measured. These young seedlings will be exposed to one of four treatments—no stress, drought, heat stress, or cold stress—then given a three day recovery period under ideal conditions. Measurements of roots and shoots before treatment and after recovery, using WinRhizo software, will be compared among treatment conditions to assess differences among cultivars. Our study will improve our understanding performance and survival of each of the cultivars in response to stress and will aid land managers in selecting appropriate seed for restoration projects.

Herbicide and Grazing Impacts on Floral Resources and Pollinator Communities. Samantha R. Nobes*, Makenzie E. Pellissier, Randa Jabbour; University of Wyoming, Laramie, WY (068)

Invasive weed species can provide floral and nesting resources to pollinator insects, influencing pollinator abundance, diversity, and behavior. Altering the landscape through weed management practices such as herbicide use and targeting grazing can affect available floral resources and pollinator dynamics. This research was part of a larger study comparing weed management strategies for Dalmatian toadflax, *Linaria dalmatica*. Treatments included untreated control, herbicide, sheep grazing, and herbicide plus sheep grazing, each replicated 4 times in 0.49 hectare plots. Chlorsulfuron 75 was applied in fall 2017 and sheep grazed each summer 2016-2018 during peak *L. dalmatica* bloom. Along a 55 meter transect, we used timed observations to count insects visiting open flowers and counted the number of open blooms per plant species in 2017 and 2018. *L. dalmatica* comprised roughly ¾ of total blooms at the site, followed by yellow sweet clover *Melilotus officinalis*, scarlet globemallow *Sphaeralcea coccinea,* and Western tansymustard *Descurainia pinnata*. Herbicide application, both when applied alone and when integrated with grazing, reduced bloom density of *L. dalmatica* as well as blooms of other forb species. Bumble bees and other native bees both utilized *L. dalmatica* as a floral resource. *L. dalmatica* and *M. officinalis* were the only species observed with bumble bee visitation. Based on our results, weed management with chlorsulfuron 75 on a grassland dominated by *L. dalmatica* will likely impact certain pollinator communities by decreasing bloom densities and floral resources.

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

Effects of Ventenata Removal on Rangelands of Northeast Wyoming. Marshall Hart*[1], Brian A. Mealor[2]; [1]University of Wyoming, Sheridan, WY, [2]University of Wyoming, Laramie, WY (001)

Ventenata (*Ventenata dubia* (Leers) Coss.) and medusahead (*Taeniatherum caput-medusae* (L.) Nevski) are newly documented invasive, annual, cool-season grasses in the northern Great Plains. In the intermountain west, loss of biodiversity, livestock and wildlife forage, increased erosion, and accelerated fire cycles are attributed to these grasses, but little is known about their ecology and impacts in the Great Plains. In cooperation with a landscape-scale management program focused on medusahead and ventenata in northeast Wyoming, we established 10 paired, treated/non-treated blocks along the boundary of ventenata stands that were aerially treated with 123 $g \cdot ha^{-1}$ of imazapic and aminopyralid each in fall of 2016 or 2017. We laid out three transects per block and collected line-point intercept canopy cover by plant species. In three $0.25m^2$ quadrats along each transect, we estimated plant canopy cover by species and collected all aboveground biomass and separated samples into functional groups before weighing and analyzing them for nutritional content. Herbicide treatments reduced annual grass (primarily ventenata) biomass ($p=0.002$), but did not increase perennial grass or total biomass. However, western wheatgrass (*Pascopyrum smithii* (Rydb) Á. Löve) increased in cover, as did bare ground ($p<0.05$). Perennial grasses had higher crude protein and total digestible nitrogen than annual grasses ($p<0.001$). Total species richness was not affected by herbicide treatment. Composite nutritive value of treated sites was not different from non-treated sites, but our forage analysis cannot account for palatability differences. Future work will focus on how forage quality and quantity change seasonally and how stability of invaded rangelands are affected by precipitation patterns.

Management of Ventenata (*Ventenata dubia*) and Other Annual Grasses with Indaziflam on Conservation Reserve Program Land. Jared A. Beuschlein*[1], Rachel J. Zuger[1], Tim Prather[2], Harry Quicke[3], Ian C. Burke[1]; [1]Washington State University, Pullman, WA, [2]University of Idaho, Moscow, ID, [3]Bayer CropScience, Windsor, CO (002)

Ventenata dubia is a winter annual grass invasive to Conservation Reserve Program lands in Eastern Washington and Northwestern Idaho. Currently, there is limited management strategies for multiple years of control and does not injure desired species. Indaziflam has been found to control invasive annual grasses such as ventenata, downy brome and medusahead. Our objective was to compare annual grass weed control in CRP with indaziflam alone or in combination with other available preemergent (PRE) products. Treatments were randomized in a randomized complete block design. These included indaziflam (102 g ai ha^{-1}), propoxycarbazone (59 g ai ha^{-1}), rimsulfuron (g ai ha^{-1}), imazapic (123 g ai ha^{-1}), glyphosate (533 g ai ha^{-1}) and mixes of indaziflam in combination with the other chemicals listed previously. Biomass was taken 91 weeks after application (WAT) by harvesting two tenth meter squared quadrats from each plot. Treatments containing indaziflam with either rimsulfuron or imazapic decreased ventenata biomass by 97% 91 WAT (nontreated: 10 g, indaziflam + rimsulfuron: 0.3 g, indaziflam +

imazapic: 0.1 g). Downy brome biomass had no significant difference between treatments 91 WAT due to low population densities. Medusahead biomass significantly decreased when treated with indaziflam and imazapic 91 WAT (nontreated: 70 g, indaziflam + imazapic: 0.1 g). Similar results were observed with all invasive grass biomass was combined over species 91 WAT. Idaho fescue biomass was higher than nontreated biomass when indaziflam was applied due to reductions in annual grass weeds. Results indicate that indaziflam has prolonged control ventenata with reduction in biomass still present almost two years after treatments were applied.

Rimsulfuron, Imazapic, and Indaziflam Interception and Sorption by Downy Brome Thatch. Shannon L. Clark*[1], Paulo V. Da Silva[2], Derek J. Sebastian[3], Scott J. Nissen[4], Rachel H. Seedorf[1]; [1]Colorado State University, Fort Collins, CO, [2]University of São Paulo - Luiz de Queiroz College of Agriculture (ESALQ/USP), Fort Collins, CO, [3]Bayer CropScience, Fort Collins, CO, [4]Colorado State University, Ft Collins, CO (003)

Invasive winter annual grass (IWAG) infestations on rangeland accumulate large quantities of thatch on the soil surface as plants senesce yearly and decompose slowly. It has been speculated that IWAG thatch can adsorb soil-applied herbicides and reduce their performance. Experiments were conducted to evaluate interception and subsequent desorption with rainfall of herbicides applied to IWAG thatch. Imazapic, rimsulfuron, and indaziflam were applied to two amounts (equivalent to 1,300 and 2,600 kg ha^{-1}) of medusahead [*Taeniatherum caput-medusae* (L.) Nevski], ventenata [*Ventenata dubia* (Leers) Coss.], and downy brome (*Bromus tectorum* L.) thatch. Rainfall was simulated at 3, 6, 12, and 24 mm at 0, 1, and 7 days (d) after herbicide application. Herbicide concentration from the collected rainfall was measured by liquid chromatography and mass spectrometry. At the high thatch amount (2,600 kg ha^{-1}), downy brome intercepted 84.3 ± 1.0% (mean ± SE) of the herbicide, while ventenata and medusahead averaged 76 ± 1.0% interception. There were no differences in desorption among the three thatch types. Simulated rainfall at 0 d after application recovered 100% of the intercepted rimsulfuron and imazapic from downy brome thatch, while recovery decreased to 65 ± 1.7% at 1 or 7 d after application. Only 54 ± 1.9% of indaziflam could be recovered at 0 d, and recovery decreased to 33 ± 1.1% when rainfall was applied at 1 or 7 d after application. Applying preemergent herbicides before forecasted rain or mixing lipophilic herbicides with a water-soluble or post-emergent partner could potentially increase the amount of herbicide reaching the soil and improve consistency in IWAG control.

Effect of Indaziflam on Native Species in Natural Areas and Rangeland. Rachel H. Seedorf*[1], Shannon L. Clark[1], Derek J. Sebastian[2], Scott J. Nissen[3], James Sebastian[4]; [1]Colorado State University, Fort Collins, CO, [2]Bayer CropScience, Fort Collins, CO, [3]Colorado State University, Ft Collins, CO, [4]Boulder County Parks and Open Space, Longmont, CO (004)

Using selective herbicides in land management is one strategy to help minimize the negative ecological impacts of exotic plant invasions; however, the unintended consequences of this strategy are not completely understood. The recently introduced herbicide, indaziflam, has a mode of action not previously used in non-crop weed management. Thus, there is limited information about the impacts of this active ingredient when applied alone or in combination with other non-crop herbicides. The objective of this research was to evaluate native species tolerance to indaziflam and imazapic applied alone and with other broadleaf herbicides. Replicated field plots were established at two locations in Colorado with a diverse mix of native forbs and grasses. Species richness and density of the non-treated control plots were compared to plots where indaziflam and imazapic were applied alone and in combination with picloram and aminocyclopyrachlor. Neither indaziflam nor imazapic alone reduced species richness and density; however, species density was reduced by treatments containing picloram and aminocyclopyrachlor. Species richness was only impacted at one site, 1 YAT, by these broadleaf herbicides. Decreases in density were mainly due to reductions in forbs that resulted in a corresponding increase in grass cover. Our data suggest that indaziflam will control downy brome (*Bromus tectorum L.*) for multiple years without reducing perennial species richness or density. If downy brome is present with perennial broadleaf weeds requiring the addition of herbicides like picloram or aminocyclopyrachlor, forb density could be reduced, and there could be a temporary reduction in perennial species richness.

Impacts of Herbicides on Invasive Annual Grasses and Desirable Plants. Hailey L. Buell*, Corey V. Ransom, Stephen L. Young; Utah State University, Logan, UT (005)

Downy brome is a highly invasive annual grass native to the Mediterranean that has spread throughout much of the United States. Indaziflam is a relatively new preemergence herbicide that has a long period of soil residual activity and has been shown to prevent germination of annual grasses for at least three years. This project was established to evaluate the efficacy of herbicides alone or in combination with indaziflam, and to determine perennial forb tolerance to various treatments. Other herbicides include propoxycarbazone, rimsulfuron, glyphosate, and imazapic. The study was established at a site near Richmond, Utah that has a variety of native and naturalized perennials and is moderately infested with downy brome. Treatments were applied November 2016 to plots measuring 6 by 18 m arranged in a randomized complete block design, replicated 4 times. Species cover was evaluated using point-line-intercept transects, recording a point every 15 cm. All treatments reduced downy brome cover. Propoxycarbazone, imazapic, and rimsulfuron reduced cover by 35, 81, and 95%, respectively. The addition of indaziflam with other herbicides increased downy brome control for all treatments except glyphosate. Glyphosate alone and all combinations including indaziflam exhibited the highest downy brome control, with cover reductions ranging from 98.5 to 100%. Rimsulfuron, imazapic, and glyphosate treatments alone increased cover of prickly lettuce. Cover of Hooker's balsamroot, a native perennial, was not altered by any treatment whereas cover of Western wheatgrass was significantly reduced in plots treated with glyphosate alone, glyphosate with indaziflam, and imazapic with indaziflam. This project provides understanding on how herbicide treatments and combinations affect plant community dynamics.

Determining Potential Soil Benefits of Established Crested Wheatgrass Versus Adjacent Cheatgrass Invasion. Emily B. Repas*, Dan R. Tekiela; University of Wyoming, Laramie, WY (006)

Crested wheatgrass (*Agropyron cristatum*) was historically seeded across the Intermountain West to stabilize heavily disturbed sites due to its ability to establish quickly in a wide variety of climates. Later observation of crested wheatgrass stands showed that it suppresses other plant growth and requires intensive management inputs to reintroduce native populations. Crested wheatgrass was banned from large scale seeding in Wyoming without understanding other potential ecological benefits it might offer besides weed suppression. After comparing soil dominated by either crested wheatgrass or an adjacent downy brome (*Bromus tectorum*) invasion, we found that downy brome soils had significantly higher nutrient pooling, whereas crested wheatgrass soils appeared to be more comparable to rangeland soils. Alteration of nutrient pooling likely favors downy brome invasion and lessens native species' ability to compete with the invasion. Crested wheatgrass as a restoration tool may help to stabilize nutrient pooling to better favor native species and lead to an easier eventual transition to a desirable vegetative state.

Variation of Seed Germination Response of *Phragmites australis* to Salinity Stress. Rose Sepesy*, Steve Young; Utah State University, Logan, UT (007)

Phragmites australis is native and invasive to North America and reproduces both asexually and sexually. Spread by sexual reproduction is affected by numerous environmental conditions. A lab study was conducted to determine germination response to salinity levels based on lineage and geographic region of the United States. Seeds (n=35) of the native and invasive lineages from California (Southwest) and Minnesota (Great Lakes) were placed on blotter paper saturated with 0, 0.5, 1, 1.5, 2. 2.5, and 3% sodium chloride solutions in a growth chamber (25°C, 12:12 DL). A greater number of the California seeds (invasive: 34, 25, 9, 3; native: 13, 11, 3, 0) germinated than Minnesota seeds (invasive: 1, 0, 0, 0; native: 4, 0, 0, 0) when exposed to 0, 0.5, 1, and 1.5% saline treatments respectively. In the California populations, invasive seed germination was over twice the native seeds with 0, 0.5, and 1% saline solutions. Only invasive seeds from California germinated at higher saline concentrations (1.5%). Germination for both native and invasive seeds from California decreased with increasing salinity. Understanding salinity resistance based on lineage and region of *P. australis* seed will aid in restoration efforts, especially when considering new population establishment. Future studies will include additional environmental conditions, such as light, temperature, residence time, and habitat.

Ecological Services of Weeds. John Vickery*; Ark Ecological Services, Arvada, CO (008)

Although not co-evolved, native animals utilize non-native plants in various settings from natural areas to ornamental plantings. Although such use is typically generalist in nature, it is nonetheless an important relationship where non-native plants comprise a significant part of the available vegetation. Native invertebrates and vertebrates utilize plants directly in the form of forage, shelter, nest materials, and perches and indirectly via the food chain. Weed control and other vegetation management activities should take these considerations into account, especially 1) whenever nonnative weeds are a substantial component of the available resources—such as nectar or pollen—at any point in time; and 2) when the wildlife species of interest is not very mobile or would find it relatively difficult to travel to and find the needed resources. The number and complexity of relationships that arise from a large number of species along with the various types of uses poses a challenge to land managers who try to control weeds or manage vegetation with wildlife in mind. However, general principles, illustrated with common scenarios and case examples provide a good starting point. Instances involving both invertebrates and vertebrates and both aquatic and terrestrial settings are presented. Weed and vegetation management scenarios, with some general categories such as chemical, mechanical, biological, and cultural control (including prescribed fire) are explored.

Accuracy and Efficiency of Drone Imagery for Detecting Elongated Mustard. Corey V. Ransom*, Heather E. Olsen; Utah State University, Logan, UT (009)

Increased availability of affordable drones and high resolution cameras provide opportunity to use these technologies for invasive species detection and inventories. A study was initiated to evaluate the use of drone imagery to detect and map elongated mustard (*Brassica elongata*), an invasive perennial mustard. Elongated mustard is a good candidate for detection testing due to its bright yellow spherical inflorescence and its scattered distribution in some areas. Against a backdrop of perennial grasses, elongated mustard was "canopy dominant", both due to height and flower color. A test area measuring 300 by 300 ft was established and outlined with tape measures for visual reference. Every elongated mustard plant within the test area was mapped on the ground using a tablet running Collector data collection app. Points were entered at the location of each plant and plant diameter was entered into the meta-data. The ground-collected points served as the most accurate representation of the number of elongated mustard plants and their canopy cover. Once the on-ground data was collected the area was flown with a hexacopter (DJI Matrice 600) carrying a high resolution camera (DJI Zenmuse X5, 10 MP) on June 19, 2018. Flights were conducted at three different heights above ground level, 20, 30, and 60 m. Flight planning software (Pix4Dcapture) was used in order to assure flight plans would collect images with enough overlap to be stitched together. Resulting images were stitched into a photomosaic and input into ArcMap and georectified based on prominent landmarks and distinct features found in the aerial and satellite imagery. Five individuals were given a brief training and asked to draw polygons containing elongated mustard using the mosaic imagery from the three flight heights. The default polygon was a circle, to match the growth habit of the mustard plants. One mapper drew rectangular polygons and was not included in the analysis. The time required for each process was noted with the exception of image download and processing. The lack of precision in the points collected on the ground and the lack of ground control points in our drone imagery limited the type of analysis we could conduct. However, the number of plants and associated acreage from ground mapping was used to compare with polygons generated using the drone imagery. The detailed mapping on the ground took two people 70 minutes. Drone flights took between 10 and 25 minutes and mapping on the computer took between 14 to 40 minutes. Interestingly, individual mapping times on the computer were fairly uniform regardless of imagery height. In some cases, the time required to collect and analyze drone images was not quite half the time required to take the detailed data on the ground. Regardless of the height from which imagery was collected, the average number of polygons identified from imagery was 24 to 28% fewer than on the ground. The standard error nearly doubled between the 20 and 60 m imagery, reflecting wide variation among mappers as imagery clarity decreased. The estimates of infested acreage were also variable and differed from the on-ground estimates by 11, 23, and 31% for the 20, 30, and 60 m imagery, respectively. The standard error associated with acreage also nearly doubled from the 20 m to 60 m imagery, reflecting more uncertainty among mappers as aerial imagery became less clear when taken at higher elevations. While drone imagery offers many opportunities for increased detection of invasive species, it does not appear well suited for detection of individual plants, and would most likely be economical only at maximum flight elevations for detection of larger patches of plants. These results need to be verified through additional testing, with greater on-ground accuracy and error controls.

Herbicide Application Timing Influences Invasive Annual Grass Control. Cody J. Beckley*, Corey V. Ransom; Utah State University, Logan, UT (010)

Medusahead (*Taeniatherum caput-medusae*) and downy brome (*Bromus tectorum*) are highly competitive invasive winter annual grasses which pose a major threat to native rangeland ecosystems of the continental United States. Preemergence herbicide applications can be an effective control method, but efficacy is highly influenced by application timing. Previous research on medusahead has indicated that applications made in October and November were generally more effective than applications made in August or September. It was thought this was due to better foliar uptake and activity and compared to soil activity against germinating seedlings. Two separate trials were initiated in 2017 on rangelands to evaluate early preemergence and postemergence herbicide application timings for impact on medusahead and downy brome control. Treatments for medusahead consisted of indaziflam, indaziflam + rimsulfuron, and imazapic applied at different timings to plots measuring 3 by 9 m arranged in a randomized block design, replicated four times. Treatments for downy brome consisted of indaziflam and indaziflam + rimsulfuron applied at different timings in a similar randomized block design. When considering preemergence suppression of medusahead, indaziflam and imazapic treatments applied in July were more effective than the same treatments made in August. The indaziflam + rimsulfuron was similarly effective for all application timings. When considering suppression of downy brome, indaziflam treatments made in July were similar to the November timing. Both timings were more effective than none, but not at a commercially acceptable level. When comparing percent cover, the November application of indaziflam + rimsulfuron was more effective at controlling downy brome than the same combination applied in July. However, both applications were similar when comparing downy brome dry weights. The results of these trials suggest that earlier application timings of indaziflam can be effective for control of highly competitive invasive annual grasses if the herbicide is moved off the thatch layer and into the soil at depths where germination is occurring. If applied after germination, indaziflam requires the addition of herbicide with foliar activity to maximize control. Future research which evaluates interaction between early herbicide applications, thatch depth, soil qualities, and rainfall should be considered.

Project 2. Weeds of Horticultural Crops

The Use of Saturated Steam in the Management of Common Landscape Weeds. Guy G. Hernandez*[1], Cheryl Wilen[2]; [1]University of California Cooperative Extension, Agriculture and Natural Resources, California State Polytechnic University, Pomona, San Diego, CA, [2]UC Statewide IPM Program and UCCE, San Diego, CA (011)

In 2000, the Healthy Schools Act required the Department of Pesticide Regulation to promote the adoption of integrated pest management (IPM) programs for California public schools and child care centers. The University of California-Agriculture and Natural Resources is conducting research and demonstration trials using mechanical methods of weed management as alternatives to herbicides near school sites. Two field experiments are underway at sperate locations in Long Beach, California. One uses saturated steam as a treatment on weeds found in tree wells, fence lines, and surrounding playground areas within a public park. The second investigates saturated steam when combined with other common mechanical methods of weed control in cracks in a parking lot. The latter demonstration study consists of five plots that were marked and randomly assigned a treatment. Treatments included an untreated control, a trim only (string trimmer), trim + steam, steam only, and a trim + steam + blowing away debris after trimming. We found that the weeds in the treated park areas were maintained for approximately three weeks before retreatment was necessary. In the parking lot, weed control trended being greatest in the trim + steam plot compared to all other treatments. When considering efficacy alone, saturated steam can be an effective form of mechanical control providing additional tools for use around school sites and other sensitive areas, as well as a short-term weed suppression as part of a schools' IPM program. However, labor costs and other factors will determine if this technology will be adopted.

Comparing Herbicides Efficacy for Sucker Control in Hazelnuts. Larissa Larocca de Souza*, Marcelo L. Moretti; Oregon State University, Corvallis, OR (012)

Hazelnuts grow as multi-stem bush because of prolific suckers growth. The common practice in Oregon is to remove suckers and promote a single trunk. Single trunks increase yields and facilitate mechanical harvest. Chemical control is the standard practice for sucker control because it is less labor intensive and more cost-effective, yet limited information is available on the performance of herbicides for this use. The objective of this study was to evaluate the efficacy of registered herbicides for sucker control in hazelnut. Field studies were conducted in commercial orchards during the spring and summer of 2018. The efficacy of the herbicides 2,4-D, glufosinate, paraquat, saflufenacil, carfentrazone, diquat, and pyraflufen alone or in combinations were compared. Efficacy of control (0-100%), sucker height and biomass were assessed 28 days after treatment. Data were analyzed by variance component analysis and indicated that herbicides accounted for 65% variance, and application timing or location explained only 2% or less than 1%, respectively. Treatments including 2,4-D or glufosinate provided 64% or greater control and were not significantly different from manual removal (80%). Paraquat and saflufenacil provided 58% and 48% control, respectively and were not different from glufosinate (65%). Pyrafluflen, diquat and carfentrazone provided 30%, 31% and 42% sucker control, respectively. Sucker height and biomass data support control observations. The herbicide 2,4-D and glufosinate are effective when used alone. Efficacy of paraquat, saflufenacil, and carfentrazone improves in tank mixtures. 2,4-D was the least expensive treatment tested, but concerns of drift and label restrictions of maximum use per season require growers to plan herbicide rotations.

Postemergence Control of Italian Ryegrass in Hazelnut Orchards. Andre C. Consonni[1], Larissa Larocca de Souza[2], Marcelo L. Moretti*[2]; [1]University of Sao Paulo, Piracicaba, Brazil, [2]Oregon State University, Corvallis, OR (013)

Italian ryegrass (*Lolium perenne* L. ssp. *Multiflorum* (Lam.) Husnot is a problematic weed in hazelnut orchards competing with the crop and compromising harvest if not controlled. Chemical control is the standard practice in hazelnut orchards, but herbicide-resistant populations of Italian ryegrass are increasingly common. To date, Italian ryegrass populations resistant to herbicides group 1, 2, 9, 10, and 22 have been found in orchards. Information on the management of these populations is required to reduce their spread. Field trials were conducted in four locations across Oregon in 2018 to tested registered POST treatments. Three out of the four orchards were selected because of reports of poor control in previous seasons (Amity, Dayton, and Salem OR), and the fourth orchard was known to be infested with Italian ryegrass (Mount Angel OR). The herbicides glyphosate, paraquat, glufosinate, rimsulfuron, flazasulfuron, and sethoxydim were tested alone or in combinations. Fifteen treatments were tested in a randomized complete block design with four replicates. Treatments were applied during the winter or early spring and results were evaluated 28 days after application (DAA). Performance of the treatments was dependent on the experimental site. Glyphosate controlled Italian ryegrass (80%) only at the Mt. Angel site. Paraquat provided 60 - 75% control in three locations, but no control was observed in the Dayton site. Rimsulfuron and flazasulfuron only controlled Italian ryegrass in Dayton and Amity (>90%). Glufosinate containing treatments provided good control (~ 80%) in all locations, and efficacy was improved (80-100%) when crop oil concentrate was added to the tank mix. However, a few plants were not controlled in the Amity location, a site where the growers reported escapes with glufosinate previously. The site-dependent response suggested that these are populations with multiple resistances. This underscores the importance of documenting site history for weed management. For now, glufosinate can control Italian ryegrass populations. Non-chemical control methods will increase sustainably of management of this prevalent weed problem.

Rimsulfuron and Oxyfluorfen+Penoxsulam Combinations for Weed Control in Tree Nuts.
Joe Armstrong*[1], Alistair McKay[2], Stephen F. Colbert[3], Dave Johnson[4]; [1]Corteva Agriscience, Fresno, CA, [2]Corteva Agriscience, Clovis, CA, [3]DuPont Crop Protection, Escalon, CA, [4]DuPont Crop Protection, Des Moines, IA (014)

Rimsulfuron, sold as Matrix®, and oxyfluorfen + penoxsulam, sold as Pindar GT®, herbicides from Corteva Agriscience™, Agriculture Division of DowDuPont, are registered for preemergence and postemergence weed control in tree nut orchards. Both Matrix and Pindar GT provide broad-spectrum control of many common key weeds in orchard production systems, including common mallow (*Malva neglecta*), marestail (*Conyza canadensis*), fleabane (*Erigeron canadensis*), annual sowthistle (*Sonchus oleraceus*), and redstem filaree (*Erodium cicutarium*). Seven field trials were conducted in 2017-2018 in California to characterize the residual efficacy of mixtures of Matrix and Pindar GT in comparison to other competitive herbicides when applied during the dormant season. Treatments evaluated in these trials included Matrix (70 g ai/ha), Pindar GT (1700 g ai/ha), indaziflam (44-51 g ai/ha), and combinations of these products. All treatments also included glyphosate and/or glufosinate to control any weeds present at the time of application. For up to four months after application, Matrix and Pindar GT alone provided good control of several weeds in these trials, including ≥80% control of redstem filaree, marestail, annual sowthistle, prostrate knotweed (*Polygynum aviculare*) and prickly lettuce (*Lactuca serriola*). Tank-mixes of Matrix + Pindar GT provided 100% control of these same species, as well as 90% control of common mallow, for up to four months after application. Similarly, combinations of Matrix + indaziflam and Pindar GT + indaziflam provided efficacy equal to or greater than indaziflam alone on several key broadleaf weeds. Matrix and Pindar GT, applied alone and in combination, also exhibited excellent crop safety in these trials.

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Wild Carrot Control in Vineyards with Flazasulfuron. Andre C. Consonni[1], Erik N. Augerson*[2], Larissa Larocca de Souza[2], Marcelo L. Moretti[2]; [1]University of Sao Paulo, Piracicaba, Brazil, [2]Oregon State University, Corvallis, OR (015)

Wild carrot (*Daucus carota* L.) is a biannual dicot plant native to the Pacific Northwest, and commonly found in perennial crops such as grapes (Vitis vinifera L). In the Willamette Valley, vineyards are rainfed; wild carrot growing in dense patches may compete for moisture during the summer. Glyphosate and glufosinate are often used in vineyards, but growers have reported poor control of wild carrot with these herbicides. The objective of this study was to evaluate flazasulfuron for controlling wild carrot in vineyards. A field study was conducted in a mature vineyard in Dallas, OR during the spring and summer of 2018. The experimental design was a randomized complete block with four replicates. Treatments tested were: (1) untreated control, (2) glyphosate 1.75 kg ae ha^{-1}, (3) glyphosate kg ae ha^{-}1 + flazasulfuron 0.03 kg ai ha^{-1}, (4) glyphosate 1.75 kg ae ha^{-1} + flazasulfuron 0.05 kg ai ha^{-1}, (5) glyphosate 1.75 kg ae ha^{-1} + flazasulfuron 0.03 g ai ha^{-1} + indaziflam 0.05 kg ai ha^{-1}, (6) glyphosate 1.75 kg ae ha^{-1} + flazasulfuron 0.03 g ai ha^{-1} + flumioxazin 0.43 kg ai ha^{-1}, and (7) glufosinate 1.6 kg ai ha^{-1}. Treatments were applied on April 23, 2018. All treatments provided good to excellent control (>80%) at the initial evaluations 14 days after application (DAA), except the untreated control. Wild carrot control with glufosinate declined to 42% at 28 DAA, and it was significantly lower than other treatments. Glyphosate provided 60% control, and it was comparable to treatments with flazasulfuron (65-77%), and indaziflam (70%), but not flumioxazin (82%). At the 90 DAA evaluation, excellent control of wild carrot was provided by treatments with flazasulfuron (88-100%), indaziflam (98%), and flumioxazin (99%). Wild carrot density was reduced to five plants m^{-2} or less in glyphosate-containing treatments, while glufosinate density was 19 plants m^{-2} and not different than untreated plots (25 plant.m^{-2}). Orthogonal contrast indicated that the addition of flazasulfuron improved the efficacy of glyphosate in controlling wild carrot. These results indicate that flazasulfuron is an effective tool for wild carrot control in vineyards.

Weed Management in Saffron. Mustapha A. Haidar*; American University of Beirut, Beirut, Lebanon (016)

Weed management is an important consideration when planting low-lying crops such as saffron. A field trial was performed in Summer/Fall of 2017 at the American University of Beirut in Lebanon to evaluate the efficacy of various weed control measures in a 4-year old saffron field. Treatments were: metribuzin (0.56 kg ai/ha, Early-POST); trifluralin (1 kg ai/ha, PPI); glyphosate (3.7 kg ai/ha, Early-POST); vetch (300 kg/ha, cover crop); and a single rototilling application. All treatments were applied in mid-September, three weeks after irrigating the field but prior to saffron emergence. Results showed that all treatments significantly reduced the level of weed infestation in saffron 40 and 60 days post-application as compared to the control. Although, vetch reduced weeds, it interfered with harvesting operations since vetch plants were taller than the saffron crop, making flower picking difficult. None of the treatments was toxic to saffron plants. The best results considering both long term weed management and selectivity in saffron were obtained by the application of metribuzin and trifluralin.

Seaside petunia (*Calibrachoa parviflora*) Effects on Onion Yield and Responses to POST Herbicides Registered for Dry Bulb Onion in New Mexico. Brian J. Schutte*, Edward Morris; New Mexico State University, Las Cruces, NM (017)

Calibrachoa parviflora (synonym: *Petunia parviflora*), commonly referred to as "seaside petunia" and abbreviated PEUPA, is a mat-forming, annual plant species that historically has been found in sandy arroyos in southwestern U.S. states and California. Farmers in southern New Mexico recently reported PEUPA infestations in fall-seeded onion. To initiate development of management recommendations for PEUPA in onion, the objectives of this study were to: (1) determine onion yield responses to PEUPA infestations that emerge during later stages of crop production, (2) determine the effects of PEUPA seedling density on the control performance of oxyfluorfen — a commonly used herbicide in New Mexico onions, and (3) compare currently registered POST herbicides for their capacity to control PEUPA at different sizes. Objectives 1 and 2 were addressed with field studies that seeded onions in October, established PEUPA infestations the following March, and harvested onions in June. For Objective 1, PEUPA densities were 0, 6 and 10 seedlings m^{-2}. For Objective 2, oxyfluorfen (280 g ai ha^{-1} with 0.25% v/v NIS) was applied POST to PEUPA patches (12 cm^2) that ranged from 1 to 24 seedlings $patch^{-1}$. Objective 3 was addressed with a greenhouse study that included factorial combinations of four herbicide treatments and four PEUPA plant sizes. Herbicide treatments were bromoxynil (420 g ai ha^{-1}), flumioxazin (70 g ai ha^{-1}), oxyfuorfen (280 g ai ha^{-1} with 0.25% v/v NIS), and a non-treated control. PEUPA size treatments, based on main shoot length, were 1 to 2 cm, 5 to 7 cm, 8 to 12 cm and 13 to 16 cm. In the field study, late-season PEUPA infestations reduced onion bulb yield by adversely affecting the production of large and medium bulbs. Oxyfluorfen provided some degree of PEUPA control if PEUPA densities were less than 3 seedlings $patch^{-1}$. In the greenhouse study, bromoxynil was the most effective herbicide as it caused the greatest percent reductions in PEUPA biomass relative to the non-treated control and terminated PEUPA plants with main shoots ranging from 1 to 12 cm in length. The results of this study indicate that (1) protection of onion bulb yield requires control of late-season PEUPA infestations, and (2) integrated management programs for PEUPA can benefit from applications of bromoxynil.

Is That Hairy Nightshade Waving at You or Smoothly Ignoring You? *Solanum physalifolium* Leaf Margins in Southern Idaho. Celestina S. Miera*[1], Brenda C. Kendall[1], Tenika S. Trevino[1], Brent Beulter[2], Pamela J. Hutchinson[3]; [1], Aberdeen, ID, [2]University of Idaho, American Falls, ID, [3]University of Idaho Aberdeen R&E Center, Aberdeen, ID (018)

Hairy nightshade is a difficult-to-control weed in potato production. The species found in the United States and Canada is *Solanum physalifolium* but has been incorrectly known as *S. sarrachoides,* a distinctly different species. Two varieties of *S. physalifolium* have been recognized: *S. physalifolium* var. *physalifolium* and *S. physalifolium* var. *nitidibaccatum* (Bitter) Edmonds. Both varieties are native to South America, however, var. *physalifolium* has not been reported elsewhere, whereas, var. *nitidibaccatum* can be found in many parts of the world. Another difference is that var. *physalifolium* only has smooth leaf margin while leaf margin of var. *nitidibaccatum* can vary from smooth to wavy to toothed. A preliminary study was conducted in 2018-2019 at the University of Idaho Aberdeen Research and Extension Center (AREC) in southeastern Idaho to better understand the leaf-margin variation in the resident var. *nitidibaccatum* hairy nightshade population, make comparisons to study results of var. *nitidibaccatum* found elsewhere in the world, and possibly determine if there are any management differences between the leaf-margin types. Berries from smooth (SS) and wavy-to-toothed (SWT) leaf-margin plants were collected from fields at the AREC September 2018. Each plant was randomly selected from a different area of the Center. No distinction was made between way and toothed leaf-margin plants. Seed was extracted from the berries, dried, then soaked in gibberellic acid for 24 hours before planting into flats in the greenhouse. Interestingly, SS seed produced both smooth and wavy/toothed leaf-margin plants, whereas, a majority of plants growing from SWT seed had wavy/toothed leaf margin and only a few were smooth leaf-margin plants. In addition, emergence from the SS seed began five weeks after planting while emergence from a majority of the SWT seed was at least eight weeks after planting. Berries will be similarly collected Fall 2019 from hairy nightshade plants at the AREC. Differences in berry characteristics, such as number of seeds per berry, will be recorded, and greenhouse trials will be conducted to determine the smooth: wavy/toothed leaf-margin ratio of plants grown from the seed. Other differences measured will include germination speed, biomass of plants produced, as well as the ratio of smooth: wavy/toothed leaf margin of second-generation plants.

Interseeded Cover Crop Tolerance to Herbicides in Non-Transgenic Sweet Corn. Andrew Donaldson*, Ed Peachey; Oregon State University, Corvallis, OR (170)

Establishing cover crops following sweet corn harvest in western Oregon can be difficult due to crop residue incorporation and fall precipitation. Interseeding cover crops midseason may reduce difficulty with fall seeding; however, in non-transgenic sweet corn, herbicide options are less flexible. Alternatively, 4-HPPD herbicides applied POST can provide effective weed control but may injure cover crops. A field trial was conducted at the Oregon State University Vegetable Research Farm near Corvallis, OR in 2018 to determine cover crop tolerance to three PRE herbicides (atrazine, S-metolachlor, and dimethenamid-P) applied 14 days before planting (DBP) and three 4-HPPD herbicides (tolpyralate, tembotrione, and topramezone) applied 7 and 0 DBP to 15 cover crop species. Cover crop survival and growth was evaluated using a 0-10 scale (10=normal growth; 0=no emergence or dead). S-metolachlor and dimethenamid-P applied at 14 DBP severely impacted the growth of all cover crops, while cereals were more tolerant to atrazine, compared to s-metolachlor and dimethenamid-P. Cover crop tolerance to 4-HPPD herbicides applied at 7 DBP was good across all cover crops, with the exception of red clover. Cover crop injury was low when tolpyralate was applied 0 DBP, while tembotrione injury was low to moderate across all cover crops except for red clover and common vetch. Topramezone applied at 0 DBP severely injured barley, red clover, buckwheat, and phacelia. These data indicate that 4-HPPD herbicides can be applied 7 DBP without compromising weed control or the growth of interseeded cover crops in sweet corn.

Project 3. Weeds of Agronomic Crops

Palmer Amaranth Interference in Sugarbeet. Whitney R. Schultz*, Nevin C. Lawrence; University of Nebraska-Lincoln, Scottsbluff, NE (019)

Glyphosate-resistant Palmer amaranth is becoming more common in the sugar beet production area of Western Nebraska. Currently, there are no POST herbicide options that are effective for its control. The competitive ability of Palmer amaranth in sugar beet has not been previously quantified. Therefore, a study was carried out in Scottsbluff, NE to measure the impact of season-long Palmer amaranth competition in sugar beet. Palmer amaranth densities were 0, 0.5, 1, 2, 4, and 8 plants row^{-1}, at a row spacing of 56cm. The study was designed as a RCBD with four replicates, with plot dimensions of 2.2 m by 9.1 m. Response variables included sugar beet yield loss, and Palmer amaranth seed production plant^{-1} and seed production m^{-2}. Using the R package 'DRC', a four-parameter log-logistic model was used to estimate Palmer amaranth seed production and a three-parameter Michaelis-Menten model was used to estimate sugar beet yield loss based upon Palmer amaranth density. At the lowest Palmer density, 0.5 plant m^{-1}, 89% yield loss was estimated. The estimated density to cause 50% yield loss was 0.06 plants m row^{-1}. Seed production plant^{-1} ranged from 19,600 to 523,300, depending on weed density. Seed production m^{-2} was similar regardless of Palmer amaranth density with an average of 189,600. This study will be repeated during the 2019 growing season using lower weed densities.

The Effect of Soil Active Herbicides on the Critical Timing of Weed Removal in Dry Bean. Clint W. Beiermann*[1], Cody F. Creech[2], Amit J. Jhala[3], Stevan Z. Knezevic[4], Robert Harveson[1], Nevin C. Lawrence[1]; [1]University of Nebraska-Lincoln, Scottsbluff, NE, [2]University of Nebraska, Scottsbluff, NE, [3]University of Nebraska-Lincoln, Lincoln, NE, [4]University of Nebraska-Lincoln, Concord, NE (020)

The critical timing of weed removal (CTWR) is the point in crop development when weed control must be initiated to preserve potential yield. A field study was conducted in 2018 near Scottsbluff, NE to determine how the use of a PRE herbicide program impacts the CTWR in dry bean. The study was arranged as a split-plot, with herbicide treatment and weed removal as main and sub plot factors, respectively. Herbicide treatment consisted of no-PRE, or pendimethalin (1070g ai ha^{-1}) + dimethenamid-P (790g ai ha^{-1}) applied PRE. Sub-plot treatment included season long weed free, weed removal at: V1, V3, V6, R2, and R5 dry bean growth stages, corresponding to 187, 287, 446, 536, and 702 GDD (base 10°C), and a non-treated weedy control. A four parameter logistic model was used to estimate the impact of weed removal, for all response variables including dry bean yield, stand, pods plant^{-1}, seeds pod^{-1}, and seed weight. The CTWR based on 5% yield reduction was estimated to be the V1 growth stage (161 GDD) in plots with no-PRE herbicide, compared to the R2 growth stage (557 GDD) when a PRE was used. The number of pods plant^{-1} and seeds pod^{-1} was reduced 73% and 22%, respectively, by delaying weed removal in the no-PRE treatment. When a PRE was applied pods plant^{-1} was reduced 26% by delaying weed removal. There was no difference in stand and seed weight across treatments. The use of a PRE in dry bean delayed the CTWR and preserved potential yield.

Horseweed (*Erigeron canadensis*) Control in No-Till Soybean Systems. Aaron M. Froemke*, Kirk A. Howatt; North Dakota State University, Fargo, ND (021)

Horseweed (*Erigeron canadensis (L.) Cronq.*) is a very competitive winter or summer annual broadleaf. It typically emerges and produces a rosette in late fall, vernalizes during winter months, and then bolts in early spring. Research was conducted to advance our knowledge of four different preemergence (PRE) residual herbicide treatments (none, saflufenacil, flumioxazin, and sulfentrazone) nested within three different soybean platforms (glufosinate, glyphosate, and dicamba plus glyphosate) for horseweed control. Results determined that horseweed control increased by more than 32% in the glufosinate and glyphosate systems with the addition of saflufenacil PRE to kill existing plants. Horseweed population was decreased by more than 50 plants per 0.5 m^2 with the addition of saflufenacil in the glufosinate and glyphosate systems. This benefit was not observed in the dicamba system due to dicamba's efficacy on horseweed since control was 99%. The addition of saflufenacil and sulfentrazone both increased horseweed percent control by more than 5% in the glufosinate system when glufosinate was applied postemergence. Saflufenacil alone only provided 67% control. This research found that dicamba, applied PRE or POST, provided excellent horseweed control and is a very effective system for horseweed infested fields. Saflufenacil controlled existing plants, but residual benefits are unclear. Further research must be done to investigate residual activity of PRE herbicides applied before horseweed emergence.

Techniques and Economic Analysis Using Weed Sensing Sprayer Technology for Fallow Weed Control. Jeremy R. Thompson*, Rachel J. Zuger, Ian C. Burke; Washington State University, Pullman, WA (022)

Weed-sensing sprayer systems activate when a weed is sensed. Sensors detect differential reflectance of chlorophyll and background soil surfaces from infrared light emitting diodes that emits infrared radiation. Such technology facilitates targeting the weeds in a precise and efficient manner and could facilitate herbicide cost and active ingredient reduction in fallow systems. A weed-sensing sprayer system may have the ability to increase the functional rate each weed receives while still decreasing the active ingredient load per acre. Our objectives were to understand the reduction of herbicide use using the weed-sensing spraying system (a WEEDit Precision System) and identify suitable herbicides for management of common broadleaf and grass weeds in fallow systems. To test the efficacy of the weed-sensing sprayer system, a study was conducted in a randomized complete design with herbicide as the main plot and application method (broadcast or sensor sprayer) as the split plot. There were 4 replications, and plots were 4.9 by 9.1 m long, and split plots were 2.4 m wide. Treatments were applied POST to weeds in a no-till residue fallow. Treatments of glyphosate, bromoxynil + MCPA ester, paraquat, saflufenacil + glyphosate, and glufosinate were applied at either a broadcast rate or spot-treatment rate depending on application equipment. Rates of herbicides were glyphosate (broadcast) 840 g ai ha^{-1}, glyphosate (sensor sprayer) 5930 g ai ha^{-1}, bromoxynil (broadcast and weed-sensing sprayer) 1120 g ai ha^{-1}, paraquat (broadcast) 560 g ai ha^{-1}, paraquat (sensor sprayer) 1320 g ai ha^{-1}, saflufenacil (broadcast) 37.4 g ai ha^{-1} + glyphosate 840 g ai ha^{-1}, saflufenacil (weed-sensing sprayer) 150 g ai ha^{-1} + glyphosate 840 g ai ha^{-1}, and glufosinate (broadcast or weed-sensing sprayer) 594 g ai ha^{-1}. Weed control was assessed by visual estimation at 1, 2, and 4 weeks after treatment (WAT), and weed biomass was hand-harvested from two 1-meter quadrats 4 WAT. The most effective treatments were glyphosate applied using the sensor sprayer, paraquat applied broadcast or weed-sensing sprayer, and saflufenacil + glyphosate, broadcast or applied using the weed-sensing sprayer. The population of weeds that qualify for spot treatment varied depending on herbicide rate and weed density but was usually less than 40% of total area treated as measured by volume of herbicide solution applied. Compared to broadcast treatments, total area treated varied considerably and ranged from 95% of the treated area to less than 20% per block. A weed-sensing system is an effective tool for delivering a higher dose of herbicide to only the target weeds in fallow systems.

Broadleaf Weed Control with Pulse-Width Modulation Technology in Wheat and Soybean. Kelly T. Satrom*, Kirk A. Howatt; North Dakota State University, Fargo, ND (023)

Pulse-width modulation (PWM) technology has been commercially available for many years, but recent industry recommendations to increase droplet sizes have increased use of PWM sprayers. Previous research in North Dakota has shown the potential for greatly reduced weed control as droplet size increases. In 2018, field trials were conducted near Fargo, Galesburg, and Prosper, ND, to investigate different droplet sizes, travel speeds, and how they interact to affect control of broadleaf weed species with four herbicide combinations commonly used in wheat or soybean production systems. Treatments in all four studies included a factorial combination of 250, 400, 600, and 750 micron droplet sizes and 8, 16, and 24 km/h travel speeds applied with a pulse sprayer plus treatments of a handboom-sprayed and untreated checks. Over all, control tended to decrease as droplet size increased. In wheat studies with bromoxynil and pyrasulfotole, control of weed species was reduced 4 to 12 percentage points as droplet size increased. New technologies such as dicamba- and glufosinate-resistant soybean varieties require the use of more course droplet sizes; however, control was greater than 90% across treatments. This was also observed with various weed species in wheat. Within wheat studies, travel speed did not have a significant effect, but within soybean trials, data showed that faster ground speed had a deleterious effect on weed control. However, more research is needed to confirm results showing the interaction of droplet size and ground speed and how they affect efficacy of various herbicides.

Non-Tolerant Wheat Response to Simulated Drift of Quizalofop-P-ethyl in Central Oklahoma. Justin T. Childers*[1], Misha R. Manuchehri[1], Vipan Kumar[2], Rui Liu[2], Jodie A. Crose[1]; [1]Oklahoma State University, Stillwater, OK, [2]Kansas State University, Hays, KS (024)

CoAXium™ Wheat Production Systems is a new herbicide tolerant wheat that allows for the use of Aggressor™ herbicide (active ingredient: quizalofop-p-ethyl) over-the-top of wheat. An increase in the use of quizalofop-p-ethyl may increase the likelihood of physical drift and/or tank contamination to nearby sensitive plants, including wheat that is not tolerant to Aggressor™. To evaluate non-tolerant winter wheat response to quizalofop-p-ethyl, studies were conducted during the 2018-19 winter wheat growing season in central Oklahoma. Fall treatments consisted of 1X, 1/10X, 1/50X, 1/100X, and 1/200X, where 1X rates equaled 62 and 92 g ai ha^{-1}. Visual crop response was recorded every two weeks throughout the growing season. At Lahoma five weeks after treatment, the 1X rates of 62 and 92 g ai ha^{-1}resulted in 72 and 80% crop injury, respectively; however, little wheat response was observed for all other rates. At Perkins and Stillwater, greater than 87% injury was observed for 1X rates of 62 and 92 g ai ha^{-1} while wheat injury for the three lowest rates, regardless of 1X rate, was similar and below 5%. Overall, significant visual wheat response five weeks after treatment was observed for both 1X rates of quizalofop-p-ethyl at Lahoma, Perkins, and Stillwater and for 1/10X rates at Perkins and Stillwater. Minor to no visual injury was observed for the three lowest rates at any site, regardless of 1X rate. Additional applications will be made this spring, yield will be recorded this summer, and trials will be replicated during the 2019-20 growing season.

Late-Season Herbicides to Suppress Downy Brome Seed Production and Progeny Fitness in Winter Wheat. Ramawatar Yadav*, Prashant Jha, Shane Leland; Montana State University, Huntley, MT (025)

Downy brome is one of the most troublesome grass weeds in winter wheat in the western US. Increasing reports of ALS inhibitor-resistant downy brome is a serious concern. Some plant growth regulator herbicides are known to cause seed sterility in grasses when applied late during the reproductive stages. Therefore, field and greenhouse experiments were conducted in 2017 and repeated in 2018 at the MSU-SARC, Huntley, MT to evaluate the effect of late-season applications of growth regulator (Group 4) and ALS-inhibitor herbicides labeled in winter wheat on downy brome seed reduction, seed viability, 100-seed weight, and progeny seedling vigor. Nine herbicide treatments were applied at early or late inflorescence stages of downy brome, within the recommended application window in winter wheat. A randomized complete block design with four replications was used. Winter wheat injury and yield were recorded. Dicamba (140 g ae ha^{-1}) or 2,4-D (518 g ae ha^{-1}) applied at the early reproductive stage (panicle initiation) suppressed downy brome seed viability by 10 to 15%, but did not influence 100-seed weight and seedling vigor. Interestingly, pyroxsulam (18 g ai ha^{-1}), mesosulfuron-methyl (15 g ai ha^{-1}), or florasulam + fluroxypyr + pyroxsulam (99+3+15 g ai ha^{-1}) at the panicle initiation timing reduced seed viability by >90%, 100-seed weight by >70%, and seedling vigor by >60%, compared to the non-treated check. In conclusion, these ALS-inhibitor herbicides applied at the panicle initiation stage of downy brome can potentially reduce late-season seed additions and progeny fitness, without affecting the winter wheat yield.

Mustard Seed Meal Effects on *Palmer amaranth* Seedbanks. Joseph B. Wood*, Brian J. Schutte, Ivette Guzman, Soum Sanogo; New Mexico State University, Las Cruces, NM (026)

Mustard seed meal (MSM), a glucosinolate (GLS) rich soil amendment, can be used to reduce weed pressure in cropping systems due to degradation products that are released upon enzymatic hydrolysis of GLS. There is little information on GLS degradation and herbicidal performance of MSM under varied soil moisture levels. The objectives of this study were to (1) determine MSM effects on Palmer amaranth seedbanks under different moisture levels, and (2) measure GLS degradation over time in soil hydrated to saturation and field capacity. To address these objectives, laboratory studies were done with seedbank mesocosms designed to maintain soil matric potentials. Seedbanks under flood, saturation, field capacity, -0.6 MPa, and -1.0 MPa were used to determine seedbank responses to MSM at a rate equivalent to 4400 kg ha-1. Changes over time in GLS were determined with soil extracts analyzed with HPLC. Results indicated that rates of MSM-induced seedbank mortality were highest in field capacity soil and lowest in saturated and flooded soils that promoted seed persistence. Saturated soil had a higher rate of GLS hydrolysis than field capacity soil, shown by a more rapid decrease in GLS. These results indicate MSM is potentially wasted in saturated soil because this causes rapid GLS hydrolysis but does not support MSM-induced mortality. Further, these results suggest that MSM-induced mortality in seedbanks requires moisture conditions that support seed germination. By understanding the relationship between moisture and GLS degradation, herbicidal effects of MSM can be maximized in irrigated cropping systems.

Economics of Cultural, Mechanical, and Chemical Weed Control Practices for Herbicide-Resistant Weed Management. Elizabeth G. Mosqueda*[1], Andrew Kniss[1], John Ritten[1], Nevin C. Lawrence[2], Prashant Jha[3], Gustavo M. Sbatella[4]; [1]University of Wyoming, Laramie, WY, [2]University of Nebraska-Lincoln, Scottsbluff, NE, [3]Montana State University, Huntley, MT, [4]University of Wyoming, Powell, WY (027)

Integration of cultural, mechanical, and chemical weed management practices are often recommended to combat the buildup of herbicide-resistant weeds in agronomic systems. The extent to which farmers have adopted integrated weed management practices is limited, in part, by risk associated with costs of adopting more diverse weed management programs. Field studies were performed from 2014 to 2017 in Wyoming, Montana, and Nebraska to see how diverse weed management programs impact economic returns of four crops grown in the Northern Great Plains when trying to manage ALS-resistant kochia. A known proportion of ALS-resistant kochia was established in 2014 before imposition of treatments. Tillage (main-plot) included annual intensive tillage or minimum tillage. Crop rotations (split-plot) consisted of continuous continuous corn, corn-sugarbeet, corn-dry bean-sugarbeet, and corn-dry bean-small grain-sugarbeet. Herbicide treatments (split-split-plot) included complete reliance on ALS inhibitor herbicides, mixtures including ALS inhibitors, or an annual rotation which relied upon ALS herbicides every other year. Crop yields were collected in 2017 after implementation of treatments for four years. Costs associated with implementation of each treatment were summed and compared to historic data from each region. An enterprise analysis was used to analyze data, and results were reported in a partial budget format. Crops treated with a herbicide mixture including ALS inhibitors that were annually intensively tilled consistently had higher economic returns than all other treatment combinations. Lowest crop returns were typically observed in ALS inhibitor herbicide treatments that were minimally tilled.

Deciphering the Molecular Basis of Multiple Herbicide Resistance in Common Watrerhemp by Whole Genome Resequencing. Balaji Aravindhan Pandian*, Sanzhen Liu, Venkatesh Prasad Ranganath, Vara Prasad P.V., Mithila Jugulam; Kansas State University, Manhattan, KS (028)

Common waterhemp (*Amaranthus tuberculatus*) is one of the troublesome weeds in the United States in crops such as corn, soybean, and sorghum. We identified amplification of *5-enolpyruvylshikimate-3-phosphate synthase* (*EPSPS*) gene conferring a high level of resistance to glyphosate in a waterhemp population from Kansas. The objectives of this research were to a) re-sequence and compare the whole genome of three glyphosate-resistant (GR) and one glyphosate – susceptible (GS) individuals and validate the copy number variation (CNV) of *EPSPS* gene determined by qPCR analysis; b) identify if any other genes have been amplified along with the

EPSPS gene; c) examine the presence of known mutations in the herbicide target genes conferring resistance to acetolactate synthase (ALS)-, photosystem II (*psbA)*-, or 4-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibitors. The GR and GS common waterhemp were sequenced using IlluminaHiSeq2500 targeting ~100 million 125bp PE reads. The raw data were trimmed and aligned to *Amaranthus hypochondriacus* reference genome. Read counts for all the annotated genes were obtained and normalized using in-house pipeline. CNV of *EPSPS* gene in GR was calculated based on differences in read counts relative to the GS common waterhemp. The *EPSPS* gene copy numbers determined by resequencing read counts were similar to those that were assessed using qPCR. Further, amplification of 18 other genes was found in both GR and GS common waterhemp individuals, including amplification of cytochrome P450 genes (four- to six-fold), which known to be responsible for herbicide detoxification in plants. We also identified a mutation ($TRP_{574}LEU$) in *ALS* gene in all the four individuals (resistant to ALS-inhibitors). No mutations were found in any another herbicide target gene examined. Whole genome resequencing is a robust tool to understand the precise molecular mechanisms conferring resistance to herbicides in weeds.

Rapid Metabolism Increases Resistance to 2,4-D in Common Waterhemp (*Amaranthus tuberculatus*) under High-Temperature. Chandrima Shyam*[1], Amit J. Jhala[2], Mithila Jugulam[1], Greg Kruger[2]; [1]Kansas State University, Manhattan, KS, [2]University of Nebraska-Lincoln, Lincoln, NE (029)

Common waterhemp in the midwestern states of the US has a broader window of emergence from low average diurnal temperatures early in the season to high temperatures in late season. 2,4-D has been widely used to manage common waterhemp in this region. Temperature is considered one of the crucial factors affecting the post-emergence herbicide efficacy. The objective of this research was to investigate the effect of temperature on 2,4-D efficacy to control 2,4-D-resistant (WHR) and susceptible common waterhemp (WHS) populations. 2,4-D dose-response studies of WHR and WHS were conducted at two temperature regimes including high (HT; 34/20 C, d/n) and low (LT; 24/10 C, d/n) temperature regimes. Additionally, the uptake, translocation, and metabolism of ^{14}C 2,4-D were also determined at 6, 24 and 72 hours after treatment. Further, to confirm the role of cytochrome P-450 monooxygenases in 2,4-D metabolism, dose-response was performed with malathion pre-treatment. Results showed an increase in resistance and a decrease in sensitivity of both WHR and WHS population to 2,4-D at HT compared to LT. GR_{50} of WHR and WHS at HT were 3696 and 176 g ae ha^{-1}, while at LT these values were 1001and 107 g ae ha^{-1}, respectively. Different growth temperatures did not affect 2,4-D absorption or translocation. However, rapid ^{14}C 2,4-D metabolism was observed in both WHR and WHS at HT compared to LT. Furthermore, pre-treatment of malathion significantly lowered 2,4-D resistance in WHR at both HT and LT. Application of 2,4-D early in the season when temperatures are cooler can improve control of 2,4-D resistant common waterhemp.

The Recent Scenario of Italian Ryegrass Herbicide Resistance Frequency and Ploidy Diversity in Western Oregon. Lucas Kopecky Bobadilla*[1], Camila R. P. Lima[2], Pete A. Berry[3], Andrew G. Hulting[1], Carol Mallory-Smith[1]; [1]Oregon State University, Corvallis, OR, [2]University of Sao Paulo, Piracicaba, Brazil, [3]Oregon State Univ., Corvallis, OR (030)

Western Oregon agriculture is largely dependent on grass seed crops including annual or Italian ryegrass (*Lolium perenne* ssp. *multiflorum*). Italian ryegrass also is one of the most important weeds in Oregon, which creates a scenario where crosses between a weed and crop can occur. Understanding the ploidy diversity of Italian ryegrass and herbicide resistance presence can help growers create strategies to avoid herbicide resistance via gene flow. The objectives of this two-year survey of 150 fields were to understand the current frequency and distribution of herbicide resistance and ploidy diversity of Italian ryegrass in the Willamette Valley. Herbicide-resistance screening was conducted in the laboratory and greenhouse. Mortality and green-leaf area reduction were used to determine if a population had resistance present. Ploidy level was measured using flow cytometry. Italian ryegrass was present in 50% of the surveyed fields and high densities of Italian ryegrass were most often found in tall fescue seed production fields. The most common types of resistance were to ACCase, ALS and EPSPs inhibitors herbicides. Multiple-resistance was identified in 23% of the fields in the survey. Nine percent of populations collected were tetraploid; however, resistance was only found in diploid plants. Herbicide resistance was spread throughout the surveyed area and clusters of multiple-resistant populations were identified. These results can serve as a base for future studies about the possible factors involved on resistance presence and test if increasing the use of tetraploid cultivars for seed production could reduce the spread of resistance via gene flow from weeds to crop.

Weed Suppression by Warm-Season Cover Crops. Greta G. Gramig*[1], Jose G. Franco[2], Kenneth P. Beamer[1]; [1]North Dakota State University, Fargo, ND, [2]USDA-ARS, Mandan, ND (031)

During recent years, farmers have been encouraged to plant cover crop polycultures instead monocultures. However, management of cover crop polycultures can be more challenging compared to monoculture management. Our objective was to compare three monoculture cover crops with two polycultures in terms of weed suppression and soil nutrient provision. Experiments were conducted during 2016 and 2017 at Absaraka ND and Fargo ND, respectively. The experimental design was an RCBD with 4 replications. Factorial combinations of cover crop (CC) species and watering regime (ambient rainfall vs. irrigated) were randomly assigned to 4.6 x 6.1 m plots. During 2016, irrigated plots were not irrigated because of high ambient precipitation. During 2017, irrigated plots were watered using overhead sprinklers once a week. Within each plot, 1 m^2 subplots were established that contained cover crops only, weeds only, or both cover crops and weeds. At peak vegetative biomass, these 1 m^2subplots were destructively harvested to obtain measurements of crop and weed density and dry biomass. During 2016 only, at the end of the growing season, a flail mower was used to terminate the cover crops. During early spring 2017, residue percent cover was estimated visually within each plot. Then cover crop residue was removed from 1m^2 subplots, dried, and weighed to determine residue biomass. After the initial flush of weeds occurred, weed density by species was quantified within these subplots and within 1 m^2 subplots containing undisturbed residue. During both years of the study, 20 - 15 cm deep soil cores were removed from each plot to determine soil N-P-K approximately midway through the growing season. Cover crop residue biomass did not differ among CC species (data not shown) but percentage residue cover was greater for foxtail millet monoculture and the three- and six-species polycultures. Foxtail millet alone, the three-species polyculture, and the six-species polyculture all suppressed weeds effectively (75, 64, and 78%, respectively), whereas cowpea alone and sunflower alone provided poor weed suppression (26 and 15%, respectively). When flail mowed, foxtail millet provided an even consistent blanket of residue. Foxtail millet alone, the three-species polyculture, and the six-species polyculture suppressed weeds better than sunflower alone (74, 77, and 82% vs. 53% suppression, respectively). The six- species polyculture also suppressed weeds better than cowpea alone (82 vs. 55% suppression, respectively). All cover crop species were suppressed by weeds to the same degree, approximately 20% on average (Figure 2, B). During 2017 in Fargo, irrigation reduced soil N from 176 to 146 lbs/acre. During 2016 irrigation treatments were not applied so no differences would be expected. At Absaraka during 2016, soil N was greater for sunflower and cowpea monocultures compared to the three-species polyculture (128 and 123 vs. 91 lbs/acre, respectively (Figure 3, A). During 2017 at Fargo, cover crop species did not affect soil nitrogen content. The differences in soil N response to cover crops between sites may have been driven by the background soil N content, which was greater at Fargo (a non-organic site). Overall, the results of this study suggest that these particular cover crop polycultures did not provide enhanced weed suppression or soil fertility compared to cover crop monocultures.

Management of Rhizoctonia Root and Crown Rot Disease in Sugar Beet with Glyphosate/Fungicide Tank-Mixes to Improve Farm Efficacy. William L. Stump*, Stephan Carl Geu; University of Wyoming, Laramie, WY (032)

Treating sugar beet seed with a fungicide prior to planting is recommended for various diseases including those caused by Rhizoctonia. However seed treatment is only effective for up to six weeks after planting at which point foliar applications of fungicide is necessary. This fungicide application typically occurs around the time the second to third application of Roundup would be applied to the beets. The goal of this project was to investigate the potential of tank-mixing Quadris, Priaxor and Proline fungicides with the glyphosate application and to determine if the chemicals will act in a synergistic or antagonistic manner in the control of weeds and Rhizoctonia root and crown rot disease (RRCR). Although research has shown that foliar banding of fungicides to be more efficacious for RRCR management, some growers continue to broadcast their foliar fungicide applications. By combining fungicide with the glyphosate application, efficacy could be drastically improved due to reduced trips across the field. Twin field plots were established in 2016-2017 at the Powell Research and Extension Center (PREC) in Powell, WY, and the Sustainable Agriculture Research and Extension Center (SAREC) in Lingle, WY. Fungicides were either co-applied or as a sequential application with glyphosate made to beets in the 8-10 leaf stage. Parameters measured included treatment effects on RRCR disease levels and weed control. Based on weed count and disease suppression data, there was no strong evidence that the co-application of glyphosate and fungicide had any impact on crop safety, herbicide, or fungicide efficacy at either site or year.

Evaluation of Flax Tolerance to Preemergence and Postemergence Herbicide Applications. Daniel Guimaraes Abe*[1], Caleb D. Dalley[1], Brian Jenks[2]; [1]North Dakota State University, Hettinger, ND, [2]North Dakota State University, Minot, ND (033)

Flax is an oil-seed crop grown primarily in North Dakota and in the Canadian Prairie Provinces. In 2018, North Dakota accounted for 85% of flaxseed production in the US with minor plantings in Montana and South Dakota. Few herbicides are registered for weed control in flax seed. Two experiments were conducted in Adams County in southwest North Dakota to evaluate preemergence and postemergence herbicides for flax tolerance and weed control. In the PRE herbicide trial, pyroxasulfone, sulfentrazone + pyroxasulfone, acetochlor, metolachlor, sulfentrazone + metolachlor, flumioxazin + pyroxasulfone, pendimethalin, flumioxazin, and dimethenamid were evaluated. Of these herbicides, injury was observed only after the application of acetochlor, with injury of 8% and 17% at 27 and 58 DAT, respectively. Stand counts and flax height were not affected by any of the applied treatments. Common mallow control was greatest (81% at 27 DAT) with sulfentrazone plus metolachlor, and was similar to sulfentrazone plus pyroxasulfone, flumioxazin plus pyroxasulfone, and pendimethalin (74 to 76%). All other treatments did not control common mallow. In the second trial, bicyclopyrone plus bromoxynil was applied at two rates (37 + 175 g ai ha^{-1} and 49 + 233 g ha^{-1}) PRE and POST (2 weeks after crop emergence). These treatments were compared with POST application of topramezone (12 and 18 g ai ha^{-1}), MCPA + bromoxynil (280 + 208 g ai ha^{-1}), bentazon (560 g ai ha^{-1}), imazamox (35 g ai ha^{-1}), and imazamox + bentazon (35 + 560 g ha^{-1}). POST application of bromoxynil plus bicyclopyrone resulted in severe injury to flax (61 to 81%), and reduced flax yield 38 to 45%, compared with the highest yielding treatment. PRE application of bromoxynil plus bicyclopyrone caused little or no injury. Topramezone caused minor injury to flax, but this injury did not reduce yield. Imazamox alone caused moderate injury to flax (29% at 15 DAT), but when tank-mixed with bentazon, this injury was reduced to 18%. Both treatments provided excellent control of common mallow and fair control of kochia and injury from treatments did not reduce yield. Results from these trials indicate that herbicides should be further explored in order to expand options for weed control in flax.

Pinto Bean Response to Low Doses of Dicamba and Glyphosate. Greg J. Endres*, Mike H. Ostlie; North Dakota State University, Carrington, ND (034)

A field study was conducted during 2015-18 at the NDSU Carrington Research Extension Center to evaluate the response of pinto bean to low dose (drift) rates of dicamba and glyphosate. Experimental design was a randomized complete block with three replications. Dicamba was applied at 0.00044, 0.0044 and 0.044 lb ae/A; glyphosate at 0.00088, 0.0088 and 0.088 lb ae/A; plus herbicide combination at low, medium and high rates to bud- to early bloom-stage (V8-R1) plants. Averaged across the four yr of the study, bean plant biomass reduction, visually evaluated 21 d after treatment, ranged from 6-19% with the low rate of dicamba, and low and medium rates of glyphosate; 22-33% with the medium rate of dicamba, high rate of glyphosate, and low and medium rates of the herbicide combination; and 48-56% with the high rate of dicamba and herbicide combination. All herbicides, except glyphosate at the low rate, delayed bean maturity compared to the untreated check, ranging from 10 to 37 d. Bean seed yield averaged 2300 lb/A with the untreated check; 1700-2160 lb/A with low rates of dicamba, glyphosate, herbicide combination, and the medium rate of glyphosate; 860-1280 lb/A with medium rates of dicamba and herbicide combination, and high rate of glyphosate; and 0-150 lb/A with the high rates of dicamba and herbicide combination. Seed germination with low rates of dicamba, glyphosate, and herbicide combination, and the medium rate of glyphosate tended to be similar to the untreated check.

Effects of Dicamba Ultra Micro-rates on Soybean Yield – Hormesis or not? Stevan Z. Knezevic*[1], O. Adewale Osipitan[2], Luka G. Milosevic[1], Jon E. Scott[1]; [1]University of Nebraska-Lincoln, Concord, NE, [2]University of Nebraska-Lincoln, Lincoln, NE (035)

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

Effects of Selected Adjuvants over Two Seasons on Weed Control in Corn and Soybeans with Glufosinate-ammonium. Jim T. Daniel*[1], Tom Hoverstad[2], Paul O. Johnson[3], Michael Owen[4], Eric Westra[5], Phil Westra[5]; [1]Daniel Ag Consulting, Keenesburg, CO, [2]University of Minnesota Southern Research and Outreach Center, Waseca, MN, [3]South Dakota State University, Brookings, SD, [4]Iowa Stae University, Ames, IA, [5]Colorado State University, Fort Collins, CO (036)

Full Load, a fully loaded water conditioning surfactant, was evaluated as part of a surfactant system with glufosinate-ammonium. Greenhouse and field trials were conducted at Colorado State University and South Dakota State University during 2017. Results showed Full Load at 0.375% or especially at 0.25% + 1.5 lb/A ammonium sulfate to be a viable surfactant for use with glufosinate-ammonium by providing weed control equal to or slightly superior to the NIS 0.25% + 3 lb/A ammonium sulfate standard. In 2018, field trials were conducted by Colorado State University, Iowa State University, University of Minnesota Southern Research and Outreach Center, Waseca, and South Dakota State University to further evaluate Full Load with glufosinate-ammonium. All experiments were conducted with a randomized complete block design with three or four replications using various small plot application equipment. These experiments had results very similar to those found in 2017.

Effective Herbicide Programs for Managing Glyphosate-Resistant Palmer Amaranth in Kansas Sunflower Production. Rui Liu*[1], Vipan Kumar[1], Taylor Lambert[1], Jeanne Falk Jones[2]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Colby, KS (037)

Glyphosate-resistant (GR) Palmer amaranth (*Amaranthus palmeri* L.) has become a serious management concern for sunflower growers in the High Plains region, including western Kansas. The main objectives of this research were (1) to evaluate the effectiveness of PRE only and PRE followed by (fb) POST herbicide programs for controlling GR Palmer amaranth in sunflower. Two separate field experiments were conducted at Kansas State University Research and Extension Center near Colby, KS in summer 2018: one for PRE only programs (Experiment 1) and one for PRE fb POST programs (Experiment 2). Both studies were conducted in a randomized complete block design, with 4 replications. The Clearfield® sunflower variety (Mycogen MY8H456GL) was planted using 57,500 seeds ha^{-1}. The study site had natural infestation of GR Palmer amaranth. All PRE herbicide programs were applied a day after sunflower planting in both studies; while POST treatments of pyroxasulfone were applied at 2,4, and/or 6 weeks after sunflower emergence (WAE) in experiment 2. Data on sunflower injury (%), Palmer amaranth visual control (%) and Palmer amaranth density were collected biweekly throughout the growing season. Data on sunflower grain yields were recorded at harvest in experiment 2. Data were subjected to analysis of variance (ANOVA) using PROC MIXED in SAS 9.3 and means were separated using Fisher's protected LSD test ($P < 0.05$). Results from experiment 1 indicated that PRE applied pyroxasulfone + sulfentrazone (155+ 155 g ha^{-1}) and pyroxasulfone + pendimethalin (178 + 1064 g ha^{-1}) had excellent control (90 to 98%) of GR Palmer amaranth throughout the season. GR Palmer amaranth control with pyroxasulfone alone and carfentrazone + sulfentrazone ranged from 51 to 89 at the final rating. Results from experiment 2 showed that PRE applied s-metolachlor + sulfentrazone (1161+ 129 g ha^{-1}) fb a sequential POST application of pyroxasulfone (75 g ha^{-1}) at 2, 4, and/or 6 WAE provided excellent and season-long control (88 to 99%) of GR Palmer amaranth, and had the highest sunflower grain yield (1584 kg ha^{-1}). All treatments had significantly lower densities of GR Palmer amaranth compared with nontreated check plots in experiments. In conclusion, growers can utilize PRE only programs, including pyroxasulfone + sulfentrazone and pyroxasulfone + pendimethalin, and PRE fb POST program such as s-metolachlor + sufentrazone fb pyroxasulfone for effective and season-long control of GR Palmer amaranth in sunflower production.

Pyraclonil: A New Broad-Spectrum Herbicide Under Field Development for California Rice. Amar S. Godar1, Kassim Al-Khatib*2, Jose Gutierrez3; [1]University of California, Biggs, CA, [2]University of California - Davis, Davis, CA, [3]Nichino America, Fresno, CA (038)

California rice production is heavily dependent on herbicides for weed control. Repeated use of herbicides has resulted in widespread herbicide resistance, however, there is no documented cases of PPO inhibitor resistance. Pyraclonil, a PPO inhibitor is widely used in the Asian rice market and would offer California rice producers another application timing for PPO inhibitors in rice. In 2018, a field experiment was conducted in Biggs, CA to determine the efficacy and rice crop safety of Pyraclonil. This experiment was arranged in a randomized complete block design. Treatments included 1.) pyraclonil, 2.) pyraclonil + benzobicyclon, 3.) pyraclonil fb. benzobicyclon, 4.) pyraclonil + clomazone, 5.) pyraclonil fb thiobencarb, and 6.) pyraclonil fb bispyribac. Weed

control was visually assessed weekly on a scale of 0-100 (0 = no control and 100 = complete mortality). Rice safety in the form of stunting and bleaching was also evaluated weekly. Rice was stunted with all treatments at 21 DAT but was within the acceptable range and recovered. Bleaching was observed at 14 DAT when pyraclonil was applied with benzobicyclon and clomazone, however at 21 DAT benzobicyclon injury had recovered and at 48 DAT clomazone injury recovered. Weed control at 42 DAT was 100 for all treatments and species evaluated. Yields were not significantly different between herbicide treatments.

Bearded Sprangletop (*Leptochloa fusca* spp. *fasicularis*) Flooding Tolerance in California Rice. Katie E. Driver*, Kassim Al-Khatib, Amar Godar; University of California - Davis, Davis, CA (039)

Bearded sprangletop (*Leptochloa fusca* ssp. *fasicularis*) is a problematic weed in California rice production. Flooding was thought to suppress bearded sprangletop growth, however after many years of continuous rice production, anecdotal evidence suggests that bearded sprangletop populations can tolerate flood pressures. A study was conducted over two years at the Rice Research Station in Biggs, CA to test the flooding tolerance of two populations against three irrigation methods. The study implemented a split block factorial design with sprangletop population being factor 1 and irrigation method being factor 2. The irrigation methods were 1) 5 cm continuous flood; 2) 10 cm continuous flood and; 3) 20 cm continuous flood. The two bearded sprangletop populations tested consisted of one clomazone resistant and one susceptible population. There was no emergence of bearded sprangletop in the 20 cm flood depth of either population. With a continuous 10 cm flood, only the resistant population survived flooding pressure and produced significantly more tillers and seed than any other treatment- population combination tested. This suggests that there may be a fitness advantage related to clomazone resistance, however further testing is needed to confirm this.

Evaluation of Florpyrauxifen-benzyl for Weed Control and Crop Safety in California Rice. Amar S. Godar[1], Kassim Al-Khatib*[2]; [1]University of California, Biggs, CA, [2]University of California - Davis, Davis, CA (040)

Florpyrauxifen-benzyl is a new postemergence herbicide for use in U.S. direct- and water-seeded rice. Florpyrauxifen-benzyl is a member of the new arylpicolinate class of auxin herbicides that exhibit unique sites of action within susceptible grass, sedge, and broadleaf weed species. The alternative mode-of-action will introduce a new herbicide resistance management tool for rice growers in a region where resistance is common. In 2018, trials were conducted at the California Rice Research Board Experiment Station in Biggs, CA to determine florpyrauxifen-benzyl efficacy and safety in California rice production. Program treatments consisted of an untreated check, florpyrauxifen-benzyl at 40 g ai ha^{-1}, florpyrauxifen-benzyl at 40 g ai ha^{-1} + cyhalofop at 271 g ai ha^{-1}, florpyrauxifen-benzyl at 40 g ai ha^{-1} + clomazone at 448 g ai ha^{-1}, florpyrauxifen-benzyl at 40 g ai ha^{-1} + benzobicyclon at 306 g ai ha^{-1}, benzobicyclon at 306 g ai ha^{-1} + penxulamGR at 40 g ai ha^{-1}, benzobicyclon at 306 g ai ha^{-1} + penoxulam SC at 40 g ai ha^{-1}. Weeds evaluated included early watergrass (*Echinochloa phyllopogon*), Rice field bulrush (*Scheoenoplectiella mucronata*), Smallflower-umbrella sedge (*Cypereus difformis*), ducksalad (*heteranthera limosa*), and heartshape false pickerelweed (*Monochoria vaginalis*).

Florpyrauxifen-benzyl alone controlled key weeds 97% or greater. Florpyrauxifen-benzyl applications controlled weeds more consistently when tank-mixed with other grass control herbicides. Florpyrauxifen-benzyl will be an effective broad-spectrum weed management tool for inclusion in full-season rice weed control programs in California.

Potential for Gibberellic Acid to Stimulate Hairy Nightshade Emergence in the Field. Don W. Morishita*[1], Pamela J. Hutchinson[2], Alexis M. Thompson[3], Rabecka L. Hendricks[1], Brent Beulter[4], Kathrin D. LeQuia[3]; [1]University of Idaho, Kimberly, ID, [2]University of Idaho Aberdeen R&E Center, Aberdeen, ID, [3], Kimberly, ID, [4]University of Idaho, American Falls, ID (041)

Hairy nightshade is considered the most troublesome weed for Idaho dry bean growers. This is because once it begins emerging it continues to germinate and emerge throughout most of the growing season. Soil-applied preemergence herbicides can effectively control hairy nightshade for only a few weeks following application. Imazamox is effective but plant-back restrictions to sugar beet and potato limit its use in dry bean. Bentazon is somewhat inconsistent. Finding some way to eliminate or reduce late season hairy nightshade emergence is desired. Soaking hairy nightshade seed in gibberellic acid can break the dormancy. This is impractical for use in the field. Finding a method to stimulate hairy nightshade germination in the field could help reduce its season-long emergence. An experiment was conducted to determine the effectiveness using gibberellic acid (GA_3) as a soil application for stimulating germination and emergence of hairy nightshade. The study was conducted at two University of Idaho research and extension centers located near Kimberly and Aberdeen, Idaho. Hairy nightshade seed was planted with a small vegetable planter at a rate of 16 seeds per 30 cm row. Plot size was 2.4 by 3.7 m with five rows of hairy nightshade. GA_3 was applied at 5 rates- 28, 42, 56, 70, and 84 g ai ha^{-1} with a plot sprayer calibrated to deliver 140 L ha^{-1} at 262 kPa. A non-treated control and GA-treated seed was included. The GA_3 was incorporated after application by two methods. The first method used mechanical incorporation with a garden rake followed by an overhead application of 1.25 cm of water. The second incorporation method used water only at the same rate previously described. At Kimberly, hairy nightshade emergence was determined by counting plants in 1.2 m of each of the 5 rows in each plot. Emergence counts were made 8, 14, 16, 18, 21, 23, 25, 30, and 37 days after the GA_3 application (DAA). At Aberdeen, hairy nightshade emergence was visually estimated in each plot 8, 23, and 38 DAA. At Kimberly and Aberdeen, hairy nightshade emergence in response to the GA_3 application peaked at 23 DAA. Maximum emergence was with GA_3 applied at 70 and 84 g ai ha^{-1} and incorporated mechanically followed by overhead irrigation. Compared to the non-treated control, hairy nightshade emergence was significantly better at Kimberly and at Aberdeen.

Palmer Amaranth Response to Glufosinate Plus Dicamba or 2,4-D Mixtures. William B. McCloskey*; University of Arizona, Tucson, AZ (042)

Does glufosinate reduce the efficacy of auxin mimic herbicides when used in mixtures to control glyphosate susceptible (GS) Palmer amaranth? The interaction of glufosinate with either glyphosate, dicamba, or 2,4-D was studied at the University of Arizona Agricultural centers in Maricopa and Red Rock Arizona in 2018. When the herbicides were sprayed individually, glyphosate resulted in greater than or equal control of Palmer amaranth compared to the auxin herbicides (i.e., dicamba or 2,4-D) which in turn provided better control than glufosinate.

Glufosinate antagonized or reduced glyphosate activity when these herbicides were mixed together and sprayed on Palmer amaranth with efficacy similar to that of glufosinate applied alone. Tank-mixing glufosinate with 2,4-D did not reduce the activity of 2,4-D on Palmer amaranth. For the most part, the same was true of tank-mixtures of glufosinate with dicamba except that the whole plot data from Maricopa suggested that the mixture could be antagonistic under some conditions. There was a similar trend in the large Palmer amaranth data but it was not significant. In contrast to the Palmer amaranth data, all of the herbicide treatments provided good control of ivyleaf morningglory. Thus, no evidence of antagonism on was found between any of the herbicides when tank-mixed and sprayed on ivyleaf morningglory indicating that interference between tank-mix partners is likely species specific. Antagonism did reduce the grass control in whole plots at MAC when tank-mixtures of glufosinate with either 2,4-D or dicamba were sprayed, again indicating that the occurrence of antagonism is species specific. These data suggest that controlling glyphosate resistant Palmer amaranth may be best achieved by spraying a tank mixture of glufosinate and 2,4-D, however, the superiority of this treatment over glufosinate plus dicamba tank-mixtures may simply be due to the greater amount of auxin herbicide acid equivalent in 2,4-D treatments. Lastly, these data reinforce the importance of spraying herbicides on small weeds in order to maximize efficacy and using sequential postemergence herbicide applications early in the season.

An Update on Multiple Herbicide-Resistant Palmer Amaranth in Kansas. Vipan Kumar*, Rui Liu, Taylor Lambert; Kansas State University, Hays, KS (043)

Multiple herbicide-resistant (MHR) Palmer amaranth (*Amaranthus palmeri*) is an increasing problem for producers in the Central Great Plains, including Kansas. A random field survey was conducted in 2014, to determine the distribution of MHR Palmer amaranth across Kansas cropping systems. Seeds of Palmer amaranth plants were collected from corn, sorghum, soybean, sunflower, and chemical-fallow fields, with a total of 175 field populations. Selected (about 31) Palmer amaranth populations were screened in 2018 for multiple resistance to glyphosate, chlorsulfuron, mesotrione, atrazine, 2, 4-D, and dicamba. Seedlings from each selected population were grown in 10- by 10-cm size square plastic pots filled with a commercial potting mix in a greenhouse at Kansas State University Agricultural Research Center (KSU-ARC) near Hays, KS. Experiments were performed in a randomized complete block design in factorial arrangement of treatments (populations by herbicides) with 12 replications and repeated. Actively growing seedlings (7- to 9-cm tall) were separately treated with discriminate dose of glyphosate (1260 g ha^{-1}), chlorsulfuron (52 g ha^{-1}), mesotrione (105 g ha^{-1}), atrazine (560 g ha^{-1}), 2,4-D (870 g ha^{-1}), and dicamba (560 g ha^{-1}). Data on percent visible injury, fresh and dry weights were determined at 21 d after treatment (DAT). Whole-plant dose-response assays were conducted on a putative MHR Palmer amaranth population collected from Barton County, KS. Based on a cut off visible injury (< 80%), resistance to glyphosate, chlorsulfuron, atrazine, and mesotrione was confirmed in 21, 16, 22, and 16 populations, respectively. Five populations also showed reduced sensitivity to 2,4-D (67 to 80% injury), while all tested populations were highly sensitive to dicamba. Dose-response assays indicated that the putative MHR population had high-level resistance to glyphosate (11.9-fold), chlorsulfuron (17.0-fold), atrazine (17.8-fold); moderate level resistance to mesotrione (7.3-fold) and low-level resistance to 2,4-D (3.5-fold). In a separate greenhouse study, alternative herbicides programs, including tank-mixture of dicamba with glyphosate, atrazine, or fluroxypyr + 2,4-D; paraquat alone or tank-mixed with atrazine, metribuzin, saflufenacil, or 2,4-D; saflufenacil alone or tank-mixed with atrazine, metribuzin, or 2,4-D; glufosinate alone or tank-mixed with glyphosate + 2,4-D, and glyphosate + dicamba; and a premix of bicyclopyrone + atrazine + mesotrione + s-metolachlor effectively controlled (≥99% injury) this MHR population. These results confirm the first report of a Palmer amaranth population with multiple resistance to five herbicide sites of action in Kansas. Growers should utilize alternative herbicides (dicamba, paraquat, saflufenacil, glufosinate alone or in tank-mixtures) for managing MHR Palmer amaranth populations.

Broadleaf Weed Control in Wheat with Halauxifen Plus Florasulam. Traci Rauch*, Joan Campbell; University of Idaho, Moscow, ID (044)

Halauxifen/florasulam is a premix herbicide formulation that was registered in wheat in August 2016 to control broadleaf weeds. Broadleaf weeds resistant to Group 2 (ALS inhibitors) herbicides may be controlled with halauxifen/florasulam (group 4 and 2). Studies were initiated in spring 2017 and 2018 to evaluate catchweed bedstraw, common lambsquarters, mayweed chamomile, and yellow mustard control in wheat. The experimental design was a randomized complete block with four replications. In 2017, catchweed bedstraw control was above 90% and similar between halauxifen/florasulam plus pyroxsulam and pyroxsulam/clopyralid/fluroxypyr at 18 and 32 days after treatment. In 2017, common lambsquarters control with halauxifen/florasulam increased as days after treatment increased (66%- 12DAT to 95% -46 DAT). Halauxifen/florasulam controlled common lambsquarters 87% at 30 DAT in 2018. Mayweed chamomile control was greater with halauxifen/florasulam alone than with halauxifen/florasulam plus bromoxynil/MCPA, bicyclopyrone/bromoxynil, and pyrasulfotole/bromoxynil in 2018. Yellow mustard control was 86% at 30 DAT with halauxifen/florasulam in spring wheat in 2018. Overall, halauxifen/florasulam will be another tool to control broadleaf weeds in wheat minor plant back restrictions for chickpea, pea and canola in our area.

Pyroxasulfone Application Timing Affects Italian Ryegrass Control in Winter Wheat. Henry C. Wetzel*, Drew J. Lyon; Washington State University, Pullman, WA (045)

Italian ryegrass (*Lolium perenne ssp. multiflorum)* is an annual or biennial grassy weed that is competitive with small grains and pulse crops in the Pacific Northwest. It is widely distributed in eastern Washington within the high rainfall zone. The objective of these field trials were to evaluate pyroxasulfone for crop safety and efficacy against Italian ryegrass in winter wheat. We evaluated herbicide application timing in relation to wheat growth stage to determine the optimum timing for Italian ryegrass control. The timings were: preplant, post-plant PRE, delayed PRE, at spike leaf and early tillering. Visual control ratings were taken when the wheat was in grain fill. This is when we see the best visual contrast between Italian ryegrass and wheat. Crop injury in the 2014/2015 trial with pyroxasulfone + carfentrazone was inconsistent among herbicide rates. This might have been caused by very dry soil conditions at seeding, which lead to variable seeding depths and non-uniform row closure. The crop injury was minor and was not reflected in yield. Crop injury was not noted with any of the pyroxasulfone treatments in the 2016/2017 or 2017/2018 trials. In the two years when the spike leaf timing was evaluated, pyroxasulfone applied post-plant PRE followed by pyroxasulfone applied at spike leaf provided excellent control of Italian ryegrass.

In two of the three years, adding an additional 0.05 lb ai/A of pyroxasulfone at early tillering improved Italian ryegrass control compared to applying only 0.1 lb/A near planting. Waiting to apply all of the pyroxasulfone at early tillering resulted in poor control of Italian ryegrass. Flucarbazone and pyroxsulam did not provide good Italian ryegrass control when applied alone and provided very little additional control when applied POST following a PRE application of pyroxasulfone. This suggests that trial areas were infested with ALS-resistant biotypes. Growers should apply the maximum annual allowable rate of pyroxasulfone for Italian ryegrass control. If the label does not allow the annual maximum to be applied prior to wheat emergence, growers should apply the maximum allowable rate preplant or PRE and apply the remainder of the annual allowable rate at spike leaf.

Is Volunteer Wheat a Serious Weed in Annual Winter Wheat Production? Judit Barroso*[1], Stewart B. Wuest[2]; [1]Oregon State University, Adams, OR, [2]USDA-Agricultural Research Service, Adams, OR (046)

Annual winter grasses are the most competitive weeds in annual winter wheat production because their life cycle, root system, and morphology are more similar to the crop than broadleaf weeds. Volunteer wheat growing in a crop of a different species has been identified as a weed. However, the effect of volunteer crops when they can add to the yield of the subsequent crop is more uncertain. The objective of this research was to evaluate the effect of volunteer wheat in wheat monoculture. Experiments where conducted in 2016 in three fields of the inland Pacific Northwest (PNW) region. Results showed averaged volunteer wheat densities between 13% and 28% in the wheat fields. Volunteer wheat produced between an 8% and 19% of the total yield. Despite the volunteer and seeded wheat both being high yielding varieties, the productivity per head of seeded wheat (0.67g) was higher than volunteer wheat (0.48g) for all the fields. The volunteer wheat behaved as a weed because the yield from the seeded wheat decreased when volunteer head density increased for all fields. When total wheat yield (seeded plus volunteer) was considered, the estimated yield loss at 120 volunteer wheat heads m^{-2} (approx. 30 plants m^{-2}) was 11.6%. In addition to the demonstrated yield loss, there are other problems that volunteer can cause such us, dockage if the wheat varieties come from different market classes, passing on herbicide resistance traits, or increasing pests or diseases in the seeded wheat. Considering all these concerns, several practices should be considered in order to minimize the density of volunteer wheat in a winter wheat field.

Using Cover Crops to Manage *Kochia scoparia* in Wheat Production Systems of the Western United States. Dani M. Thiemann*[1], Stephen L. Young[2], Earl Creech[2], Corey V. Ransom[2], Don W. Morishita[3]; [1]Utah State University, Nibley, UT, [2]Utah State University, Logan, UT, [3]University of Idaho, Kimberly, ID (171)

Kochia scoparia (kochia), an invasive broadleaf weed, is problematic throughout the world, especially arid and semiarid Western US. Rapid seed dispersal, early emergence and a broad range of tolerances, including herbicide resistance, allow kochia to be an effective competitor against crops. By incorporating cultural and physical tools along with herbicides, our goal is to promote more competitive crops against kochia and other weeds. A 1-year field study was conducted to determine the effect of crop planting dates, seeding rates and weed control methods (herbicide,

cover crops and a combination of cover crop and herbicide) on populations of kochia and other weeds in wheat in the Intermountain West. At Kaysville, UT, weed cover was significantly lower in the combination treatment (3.5±3.89%, p=1.033e-05), about ten times lower than none treated plots (30±21.53%) by mid-season. At harvest weed biomass was lowest in the combination control treatment (11.76±4.42g, p=0.0002189), almost half the weed biomass seen in none treated controls (20.33±5.86g). At post-harvest weed biomass was lowest in the combination and cover crop treatments (3.74±2.54g; 3.99±2.74g, p=2.065e-06), demonstrating continued presence of cover crops can potentially limit weed encroachment. At Cache Junction, UT, herbicide followed by the combination treatment were most effective in suppressing kochia (0±0%; 0.2439±1.25%) and general weeds cover was significantly reduced by the combination control treatment (2.561±6.38%, p=0.008183). At harvest and post-harvest weed biomass was significantly decreased in the combination treatments (3.25±4.32g, p=0.007114; 7.775±8.27g, p=0.03783). The use of cover crops interplanted in irrigated spring wheat can be effective in suppressing kochia and other weeds, although additional studies are needed to better understand weed- cover crop- crop competition.

Project 4. Teaching and Technology Transfer

A Short Course on Herbicide Modes of Action and Herbicide Resistance. Tom Mueller*[1], Todd A. Gaines[2], Dale Shaner[2], Franck Dayan[2]; [1]University of Tennessee, Knoxville, TN, [2]Colorado State University, Fort Collins, CO (047)

Weed control has faced many challenges over the years, and herbicides have greatly aided farmers and others in their efforts to reduce weed's negative effects. In broad acre crops, Glyphosate Resistant (GR) varieties have been commonly used in overly simple weed control regimes in soybeans, cotton, corn and other crops. The widespread occurrence of GR weeds has reduced the utility of GR crops, and has resulted in a renewed interest in alternate herbicide chemistries.

This poster details an educational short course to be held in 2019 that covers the various modes of action and also herbicide resistance to those various chemicals. Practical aspects of herbicide use and optimization of weed control strategies are important topics extensively covered in this course.

Educating Constituents About Herbicide Injury to Non-Target Plants. Noelle Orloff*[1], Jane Mangold[2], Tim Seipel[2]; [1]Montana State University Extension, Bozeman, MT, [2]Montana State University, Bozeman, MT (048)

Herbicide injury to non-target plants is a continuing concern in Montana. For example, plant samples assessed for non-target herbicide injury symptoms by Montana State University's Schutter Diagnostic Lab increased by 90% between 2013 and 2018, from 60 to 115 samples per year. In response to these issues, we have implemented a series of hands-on, interactive workshops for constituents to gain experience diagnosing symptoms and understanding causes of non-target injury. Our workshops include scenarios in both agricultural and residential settings where non-target herbicide injury may occur, including synthetic auxin contamination of vegetable farms and gardens through compost, manure and topsoil; carryover in agricultural fields due to new crop rotations; increased residual times due to drought or soil acidification; and herbicide drift. Target audiences include Extension agents and county weed coordinators, private and commercial pesticide applicators, agricultural producers, and gardeners. Between 2017 and 2019 we have conducted 12 presentations and workshops reaching over 400 participants. The workshops have been well received by audiences, with an average 4.6 rating (scale of 1 – 5 with 1 = poor and 5 = excellent). We have received many comments from participants reporting that the hands-on nature of the workshops is beneficial for learning about herbicide injury diagnosis and improving understanding of herbicide modes of action. In the next two years, we plan to develop a teaching module for educators like Extension agents and county weed coordinators so they may conduct similar workshops in their own communities.

WSSA Advocates for Weed Controls that Protect Soybean Export Value. Carroll Moseley[1], Lee Van Wychen*[2], Heather Curlett[3], Jill Schroeder[4], Patsy Laird[1], Shawn P. Conley[5]; [1]Syngenta, Greensboro, NC, [2]WSSA - Executive Director of Science Policy, Alexandria, VA, [3]USDA-APHIS, Riverdale, MD, [4]New Mexico State University, Arlington, VA, [5]University of Wisconsin-Madison, Madison, WI (049)

Weeds and weed seeds are a serious phytosanitary concern. Most countries, including the United States, take action when weed seeds are detected in arriving shipments. The importing country may reject, re-export, or destroy the shipment. In the worst case, the country may suspend imports or close the market altogether. Soybeans are one of the United States' top exports. Increases in herbicide-resistant weeds may be contributing to more weed seeds in harvested beans. There are a number of best practices, many of which are already in use here in the United States, that can be applied on farm and by grain handlers to help reduce weed seeds in U.S. soybeans.

Fresh Ideas for Teaching Organic Pest Management in the Classroom. Randa Jabbour*, Makenzie E. Pellissier; University of Wyoming, Laramie, WY (050)

Organic agriculture course offerings continue to become more common at colleges and universities in the United States, and often reflect instructor expertise or regional issues of concern. The goal of this project was to develop multi-regional organic agriculture undergraduate curriculum at the introductory level for diverse student audiences. Here, we will present the module focused on pest management - including weed, insect and pathogen management. We made a film series with certified organic producers from around the United States, available at bit.ly/orgproducer. Weed management is mentioned in a few different examples in the pest management video, and also around issues related to organic compliance. We built an assignment around the film that students can use to learn about different pest management practices. We also created a web-based assignment to navigate prohibited and allowable substances in certified organic production. All modules are available at the Sustainable Agriculture Education Association website, in their teaching resources library. Project made possible with funding from the USDA National Institute of Food and Agriculture Organic Agriculture Research and Extension Intitiative #1007232.

Project 5. Basic Biology and Ecology

Fate of Glyphosate During Production and Processing of Glyphosate-Resistant Sugar Beet (*Beta vulgaris*). Abigail Barker*, Franck Dayan; Colorado State University, Fort Collins, CO (051)

Glyphosate is a widely used herbicide in commercial crop production for both conventional and herbicide-resistant crops. Herbicide-resistant crops, like glyphosate-resistant sugar beet, are often exposed to multiple applications of glyphosate during the growing season. The fate of this herbicide in resistant crops has not been publicly documented. We investigated the fate of glyphosate and main metabolite aminomethylphosphonic acid in glyphosate-resistant sugar beet grown in northern Colorado. Glyphosate residues were measured via directed ultra-high-performance liquid chromatography tandem mass spectrometry analysis of sugar beet shoots and roots throughout the growing season, from samples collected at various steps during sugar beet processing, and from flow-through samples of greenhouse-grown beets. Sugar beet rapidly absorbed glyphosate after foliar application, and subsequently translocated the herbicide to its roots, with between 2 and 3 μg/g fresh weight measured in both tissue types within 1 week of application. However, only trace amounts of glyphosate remained in either the shoots or the roots 2 weeks after application. Analysis of irrigation flow-through in pot assays confirmed that the herbicide readily exuded out of the roots. Processing of the beets removed glyphosate and herbicide levels were below the limit of detection in the crystalline sugar final product.

Response of Glyphosate-Susceptible and Resistant Palmer Amaranth to Environmental Stresses During Germination and Growth. Samikshya Budhathoki1, Lynn M. Sosnoskie*2, Anil Shrestha1; [1]California State University, Fresno, CA, [2]University of California - Davis, Davis, CA (052)

Much of the area in California's southwestern San Joaquin Valley (SJV) is prone to moisture stress and high soil-salinity conditions. In recent years, glyphosate-resistant (GR) biotypes of (*Amaranthus palmeri)* have been confirmed in the SJV. However, it is not known if these biotypes are more- or less-fit than the glyphosate-susceptible (GS) biotypes in such environments. Therefore, two studies were conducted to assess the effect of a) moisture stress and salinity on the germination of a confirmed GR and a GS biotypes of Palmer amaranth, and b) salinity on the growth of these biotypes. Moisture stress at germination was simulated by preparing polyethylene glycol solutions ranging from 0 to 5.56 MPa. Salt stress at germination was assessed under sodium chloride solutions ranging from 0 to 25 dS m^{-1}electrical conductivity (EC). Germination tests were conducted in petri dishes lined with filter paper and placed in a controlled environment chamber set at 25° C. The experiment was arranged as a completely randomized design and data were analyzed using analysis of variance ($\alpha = 0.05$) and non-linear regressions. Effect of salinity on these biotypes were also assessed by monitoring growth of potted plants kept outdoors under sodium chloride solutions ranging from 0 to 20 dS m^{-1} EC. Germination of GR and GS seeds were affected differentially by EC. The GR seeds exhibited greater germination at a higher EC than the GS seeds. Approximately 8% of the GR seeds germinated at 20 dS m^{-1} whereas, only 2% of the GS seeds germinated at 15 dS m^{-1}. However, both biotypes showed similar response in germination to moisture stress. Approximately 25% of the seeds germinated at -0.51 MPa and there was no germination at the lower water potential levels. Both GR and GS plant growth was affected similarly by EC. The total aboveground dry biomass decreased curvi-linearly with increasing EC levels. Averaged over biotypes, biomass at 5, 10, 15, and 20 dS m^{-1} was 100, 76, 49, and 42% of the control (0 dS m^{-1}), respectively. Results from these studies suggest that the GR population used in the trial is not less fit than the GS biotype, under the conditions of these studies. In 2018, seed samples from Palmer amaranth and common waterhemp (*A. tuberculatus*) populations were collected from several areas of the Southern SJV to describe their responses to herbicides and environmental stresses.

Environmental Effects on Chemical Management of Junglerice (*Echinochloa colona*). Anil Shrestha*, Ryan Cox, Mala To, Samikshya Budhathoki, Katrina Steinhauer; California State University, Fresno, CA (053)

Junglerice is a problematic weed in annual and perennial cropping systems in California. Although there are several postemergence herbicides labeled for its control in orchards and vineyards, it was suspected that their efficacy could be influenced by shade and soil moisture. Therefore, studies were conducted in summers of 2015 -2018 to assess the efficacy of glyphosate, glufosinate, and sethoxydim on junglerice plants growing under various soil moisture [100% field capacity (FC), 75% FC, and 50% FC)] and shade (Full Sun, 70% of Full Sun, and 50% of Full Sun) conditions. Label rates of the herbicides were applied at the 4- to 6-leaf stage of junglerice and the plants were immediately put under the abovementioned conditions for 4 weeks. Plant mortality was evaluated at 28 days after treatment. The plants were then harvested, oven-dried, and their aboveground biomass was recorded. There was no year by factor interactions ($P>0.05$). Therefore, data for the four years were combined. Plant mortality was affected by shade, moisture, and herbicide type. Both shade and soil moisture conditions influenced the efficacy of the herbicides. Mortality, in general, was greater under 50 and 70% shade than in the full sun for all herbicides. Glyphosate was influenced more by the level of shade and moisture than glufosinate or sethoxydim. Glyphosate efficacy was greater under wetter soil conditions in the shade and drier conditions in the full sun. Such differences were less noticeable for glufosinate. Aboveground dry matter was greater in the full sunlight than in the 50 and 70% shade levels; however, there was no difference between the 50 and 70% treatments. Shade and soil moisture levels may have to be taken into consideration while applying glyphosate (and to some extent sethoxydim) for control of junglerice. Glyphosate-escapes of junglerice may be more noticeable in the drier non-shaded areas in orchards and vineyards. Further studies should be conducted to ascertain the physiological reasons for such.

Emergence Dynamics of Palmer Amaranth Populations from the Central Great Plains. Vipan Kumar*[1], Rui Liu[2], Misha R. Manuchehri[3], Nevin C. Lawrence[4], Muthu K. Bagavathiannan[5], Todd A. Gaines[6]; [1]Kansas State University, Hays, KS, [2]Kansas State University, hays, KS, [3]Oklahoma State University, Stillwater, OK, [4]University of Nebraska-Lincoln, Scottsbluff, NE, [5]Texas A & M University, College Station, TX, [6]Colorado State University, Fort Collins, CO (054)

Multiple herbicide-resistant Palmer amaranth is a serious management concern in the Central Great Plains (CGP), including Kansas. An improved understanding on emergence characteristics of Palmer amaranth populations is required to develop effective management strategies in this region. To fulfill this research gap, a field study was initiated at Kansas State University Agricultural Research Center near Hays, KS in 2018. Nine Palmer amaranth populations collected from Colorado (CO1, CO2), Oklahoma (OK), Kansas (KS1, KS2), Texas (TX), Nebraska (NE1, NE2, NE3) were included. The study was conducted in a randomized complete block design, with 4 replications. Two hundred seeds from each selected population were uniformly sown on soil surface inside an open-ended cylindrical PVC rings (30-cm diam) on March 30, 2018. The number of emerged seedlings were counted and removed on weekly basis until the cessation of any further emergence (April 29 through August 30). Cumulative emergence was calculated based on the percentage of total emergence during the growing season. The cumulative emergence data were analyzed using a 3- parameter log-logistic regression model. Cumulative growing degree days (cGDD, T_{base} 16.6 C) were used to predict the Palmer amaranth emergence. Among all populations, CO1 emerged earlier, with a minimum of 3 cGDD required for 10% (E_{10} value), 19 cGDD required for 50% (E_{50} value), and 112 cGDD required for 90% (E_{90} value) cumulative emergence. In contrast, the seedlings emergence of OK and TX populations was delayed, with 20 to 30 cGDD required for 10%, and 68 to 79 cGDD required for 50% cumulative emergence. Lower negative values of *b* parameter for OK (-2.2) and TX (-1.8) populations further indicated their lower emergence rates (slower in dormancy release) as compared to other populations. No significant differences in the cGDD required for 90% cumulative emergence were observed among all the populations. Results suggest that Palmer amaranth populations from the CGP region had differential emergence patterns under semi-arid dryland environment. Based on these results, growers would need site-specific and multi-tactic strategies to manage the Palmer amaranth seedbanks on their production fields.

Comparing the Effects of Simulated Auxin Herbicide Drift on Winegrapes. Junjun Ou[1], Brad Hanson*[2], Kassim Al-Khatib[2]; [1]University of California, Davis, Davis, CA, [2]University of California - Davis, Davis, CA (055)

Grapes are well known to be highly sensitive to damage from auxinic herbicides, with visible leaf symptoms occurring soon after exposure to even relatively low drift rates of these herbicides. Because these herbicides are widely used in both cropland and noncrop areas, there are frequent allegations from winegrape growers related to crop injury from auxinic herbicides in California vineyards. With the recent development of 2,4-D- and dicamba-resistant crops, there has been increasing concerns and questions from grape growers in other parts of the country about identifying and quantifying the damage from the drift of different auxinic herbicides. This study was designed to compare the relative sensitivity, symptomology, and yield reduction of winegrapes that exposed to simulated drift of four auxinic herbicides under field conditions. Treatments were applied at 1/900, 1/300, 1/100, and 1/33 of a recommended field rate of the auxin herbicides 2,4-D, aminopyralid, dicamba, and triclopyr. The vineyard was a mature Grenache winegrape vineyard trained to a two-wire vertical trellis and the experimental design was a randomized complete block with three replicates and each plot consisted of two vines. Treatments were applied using a 2-nozzle spray boom calibrated at 20 GPA to one side of the canopy on June 13, 2018 at the fruit set stage. Visual injury was evaluated during the remainder of the growing season and the fruit was harvested and weighed when the average sugar content in berries in the nontreated plots reached to 20 °Brix. Although the severity of the visible damages was rate dependent, all simulated rates of the four herbicides resulted in tendril and apical death on developing branches from 7 to 30 days after the application of drift at the fruit set stage, and they all induced inconsistent color development during veraison stage. The most prevalent symptoms in this study were leaf malformations such as leaf cupping from aminopyralid and dicamba, and leaf strapping from 2,4-D, while triclopyr usually caused leaf chlorosis and desiccation instead of abnormal leaf growth. Although, all these different symptoms were observed after treatment, only triclopyr at 1/100 and 1/33 of 2240 g ae ha^{-1}significantly reduced grape yield and concurrently increased the brix levels of the fruit. In conclusion, though winegrapes were sensitive to drift of all four tested herbicides and prone to develop damaging symptoms, fruit yield was not statistically reduced from a single exposure to 2,4-D, dicamba, and aminopyralid at as high as 1/33 of commonly used field application rate of each herbicide. However, significant grape yield loss and brix increases can be caused by a triclopyr drift at a 1/100 or more of field application rate onto the vines. This experiment will be monitored in the year following the initial application to evaluate effects on spring vegetative growth and will also be retreated to evaluate the impacts of recurrent exposure as could happen in regions with widespread use of auxinic herbicides.

Weed Emergence Timing and Shade Avoidance Responses in Sugarbeet. Albert T. Adjesiwor*, Andrew Kniss; University of Wyoming, Laramie, WY (056)

Experiments were conducted at the University of Wyoming in 2018 to evaluate the response of sugarbeet (*Beta vulgaris* L.) to timing of weed-reflected far-red light (shade avoidance signals) removal. A large-pail field study included a range of weed addition and removal timings to quantify sugarbeet growth parameters and yield. The model weed, Kentucky bluegrass (*Poa pratensis*) was grown in a separate container from sugarbeet so there was no root interaction, and the grass was clipped regularly to prevent direct shading of the sugarbeet plants. There was adequate soil moisture and nutrients so there was no growth limitation due to either moisture stress or nutrient deficiency. When weeds were present near sugarbeet between sugarbeet emergence until the 2 true-leaf stage, most sugarbeet growth and yield measurements were similar to sugarbeet surrounded by weeds for the duration of the season. For example, compared to the weed-free control treatment, season-long weed presence reduced sugarbeet root fresh weight by 32% while removing weeds at the 2 true-leaf stage reduced sugarbeet root fresh weight by 33%. Similarly, sugarbeet leaf number, leaf area, and shoot biomass were reduced 15, 27, and 27%, respectively by both the season-long weedy treatment and 2 true-leaf removal treatment. Exposing sugarbeet to shade avoidance signals during emergence might result in substantial loss of yield potential even if weeds are removed by the 2 true-leaf stage.

Ecological Strategies to Manage Herbicide-Resistant Kochia Seed Bank in the Western US. Prashant Jha*[1], Andrew Kniss[2], Nevin C. Lawrence[3], Ramawatar Yadav[1], C A. Lim[1]; [1]Montana State University, Huntley, MT, [2]University of Wyoming, Laramie, WY, [3]University of Nebraska-Lincoln, Scottsbluff, NE (057)

Stakeholders from across the northern and central Great Plains of the US have identified kochia (*Kochia scoparia*) as one of the most problematic and economically damaging summer annual weeds. This tumbleweed is currently a threat to sustainable crop production due to a near lack of effective herbicide options, especially in sugar beet-based crop rotations in this region. Widespread resistance to many different herbicides (including glyphosate, atrazine, ALS inhibitors, and dicamba) has increased the need for IWM-based solutions for managing this weed. For this multi-year (2017-2020) research conducted in Huntley, MT; Powell, WY; Lingle, WY; and Scottsbluff, NE; we propose: 1) quantifying temperature and moisture germination requirements of kochia accessions collected from the north-south transect (from Montana to Nebraska) and 2) using that information to evaluate the effectiveness of three ecologically-based IWM strategies, including stale seedbed, cover crop, and diversified crop rotations. We will combine field-validated emergence data, hydrothermal time modeling, and climate data (2019-2020) to evaluate non-herbicidal weed control strategies (stale seedbed, cover crops, and diversified crop rotations) that have a high likelihood of reducing kochia seed bank and exposure of this species to herbicide treatments, thereby reducing selection for herbicide resistance evolution. We observed differences in kochia germination pattern across the north-south transect at suboptimal temperatures and water potentials, with accessions from north being more adapted to low temperatures and water potentials. This indicates that a stale seed bed approach in early spring would be a more viable strategy in the southern region (Lingle and Scottsbluff) to stimulate kochia germination and exaust the seed bank with subsequent tillage or alternative non-selective herbicides prior to planting dry beans (1st week of June), grown in rotation with sugar beet. Inclusion of an early-planted (April) and early harvested (July/August) wheat/barley crop and a late-planted dry bean crop in the traditional corn-sugar beet rotation can drastically reduce herbicide-resistant kochia seed banks at a cropping systems level. Implementation and adoption of these ecologically-based IWM strategies will reduce potential environmental impacts associated with increased herbicide use, apart from mitigating herbicide resistance.

Winter Wheat Above Ground Growth Changes Due to Being a Neighbor to Different Species. Osama S. Saleh*; University of Wyoming, Laramie, WY (058)

In dense plant canopies, there is a reduced red (R) to far-red (FR) light ratio because most plants absorb R light but transmit or reflect FR light. Reduced R:FR induces physiological and morphological changes which affect plant growth and development. Three sets of experiments were conducted in the greenhouse in 2018 to evaluate the response of winter wheat (*Triticum aestivum* L.) to reflected light from different species. Winter wheat was grown in plastic containers and surrounded by either wheat, jointed goatgrass, downy brome, prickly lettuce, western salsify, dandelion, kochia, common lambsquarters, or redroot pigweed. The experimental design was a randomized complete block with 12 replicates. The experimental setup ensured that there was no underground competition. Wheat chlorophyll content was measured three times: 25, 45, and 60 days after planting (DAP). At the end of the experiments, the aboveground growth characters were measured. Jointed goatgrass had the least R:FR ratio (0.098) while prickly lettuce, western salsify and dandelion had the highest R:FR ratio (0.14, 0.17, and 0.21 respectively). Wheat chlorophyll concentration decreased with time after planting, but there were no wheat chlorophyll concentration differences among treatments (P= 0.2032). Jointed goatgrass decreased wheat tillers 43% and the number of wheat leaves by 44% while western salsify increased the number of wheat tillers 52%. There was no significant effect of neighboring species on wheat shoot height (P=

0.2321). In general wheat biomass was decreased except in kochia and common lambsquarters treatments (*P*= 0.0274).

Weed and Crop Discrimination with Hyperspectral Imaging and Machine Learning. Prashant Jha*[1], Joseph A. Shaw[2], Bryan J. Scherrer[2], Vipan Kumar[3], Ramawatar Yadav[1], J Anjani[1], Shane Leland[1]; [1]Montana State University, Huntley, MT, [2]Montana State University, Bozeman, MT, [3]Kansas State University, Hays, KS (059)

Widespread resistance of weeds to many different herbicides including glyphosate in the U.S. has increased the need and desire for IPM-based remote scouting tools for "early detection and rapid response" to mitigate resistance. Our preliminary experiments showed that hyperspectral imaging was capable of providing automated detection of herbicide-resistant kochia prior to any herbicide application, leading to a robust detection algorithm. We applied the algorithm to identify herbicide-resistant, mostly glyphosate-resistant biotypes vs. -susceptible biotypes, of three weed species (kochia, common lambsquarters, and horseweed) in outdoor field conditions using a ground tripod-mounted and an aerial UAV-based hyperspectral imaging platforms. The algorithm was able to discriminate each crop (corn, sugar beet, wheat, barley, and soybean) from the weeds (kochia, horseweed, and common lambsquarters) with near perfect accuracy. Once the weed species have been discriminated against each other, the algorithm can more clearly classify herbicide-susceptible and -resistant biotypes in different crops. In our analysis, we used the average reflectance spectra of several different resistant and susceptible biotypes (populations) of each weed species in the visible and NIR wavelengths to develop classification images. The algorithm classified glyphosate-resistant and -susceptible horseweed at least 99% of the time. The classification accuracies for susceptible kochia and all five resistant biotypes were 96% and 85%, respectively. Glyphosate-resistant and dicamba-resistant kochia were discriminated from one another with 80% and 63% accuracy, respectively. Glyphosate-resistant and susceptible lambsquarters can be discriminated against each other almost perfectly. An analysis of kochia plants at each stage of its development revealed that the classification accuracies heavily depend on the plant age. We found that kochia biotypes imaged when they were about two weeks old compared to when they were 7 to 8 weeks old were easier for our algorithm to discriminate, correctly discriminating between glyphosate- and dicamba-resistant kochia with 99% accuracy. Implementation and adoption of this hyperspectral remote-sensing IPM tool will translate into site-specific herbicide resistance management.

GENERAL SESSION

Introduction – Meeting Announcements. Pat Clay*; Valent U.S.A. LLC, Fresno, CA, WY (172)

Digital version of the program:

Check your email for: 72nd Meeting of the Western Society of Weed Science invitations@guidebook.com or https://guidebook.com/g/6r34nqul2lrpogoeqh4v-2019wsws/
Or https://guidebook.com/. Find a Guide tab and search WSWS

Program Changes:

- One poster added to Graduate Contest (#171)
- One poster withdrawn from Graduate Contest (#22)
- One poster withdrawn (#63)
- Two papers withdrawn (#100, #136)
- One paper withdrawn from contest (#101)
- Rights of Way Symposium changes in presentation order and time slots
- Printed copy of changes will be provided

Continuing Education/Pesticide Recertification Credits:

Credits at this meeting available for:

- AZ, CA, MT, NV, NM, WA, WY

WSWS can not meet requirements for CEUs from:

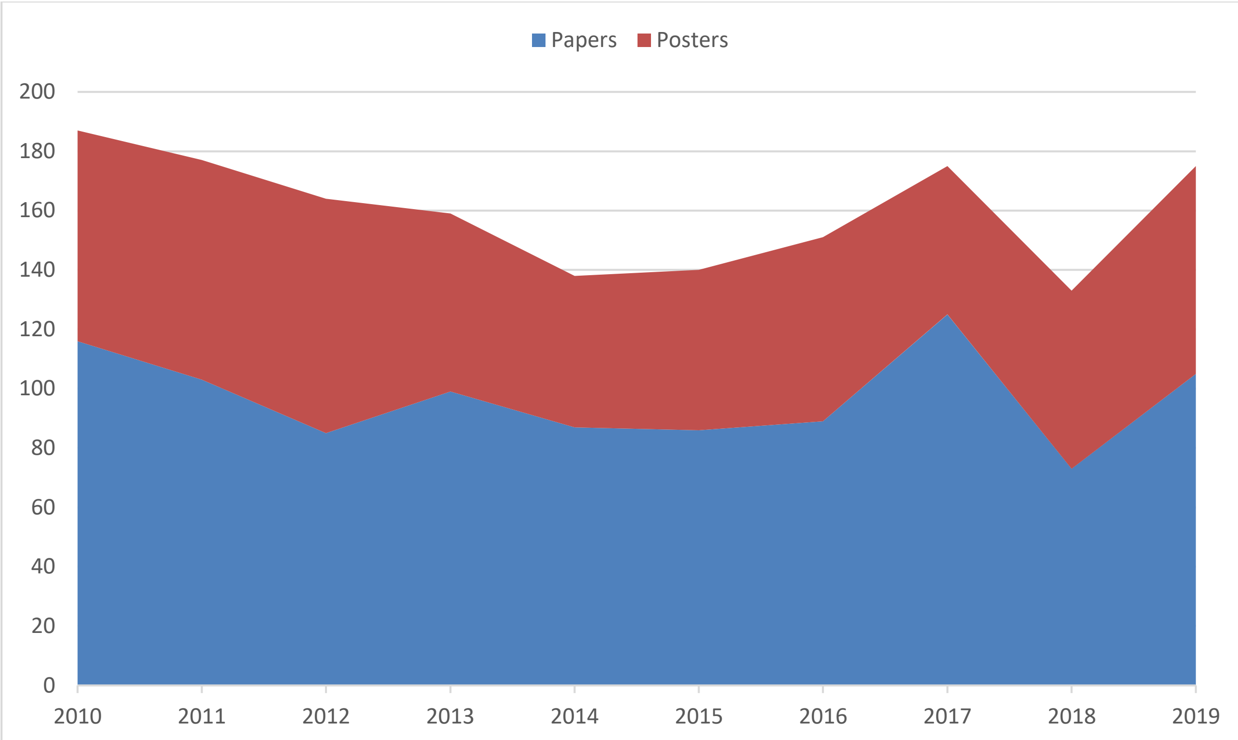
- CO, OR

Sign in sheets:

- AZ, NM, ,NV, WY at registration desk
- Scantrons for CA available at registration desk – one required per person per session
- The rest either at registration desk or at entrance to session
- Verification or authentication required for several states
- License holders are ultimately responsible for authenticity
- Special thank to Brian Schutte, Beth Fowers (WY), and Kai Umeda (AZ)

Symposia:

- "Integrated Pest Management Research in the West"
  Wednesday, 1:45 to 3:25 – Mt. Sopris A
- "Rights-of-Way – Beyond Integrated Vegetation Management to Integrated Habitats!"
  Thursday, 9:30 to 3:00 – Colorado Ballroom A
  Lunch Included, 12:00 to 1:00 – Aspen Ballroom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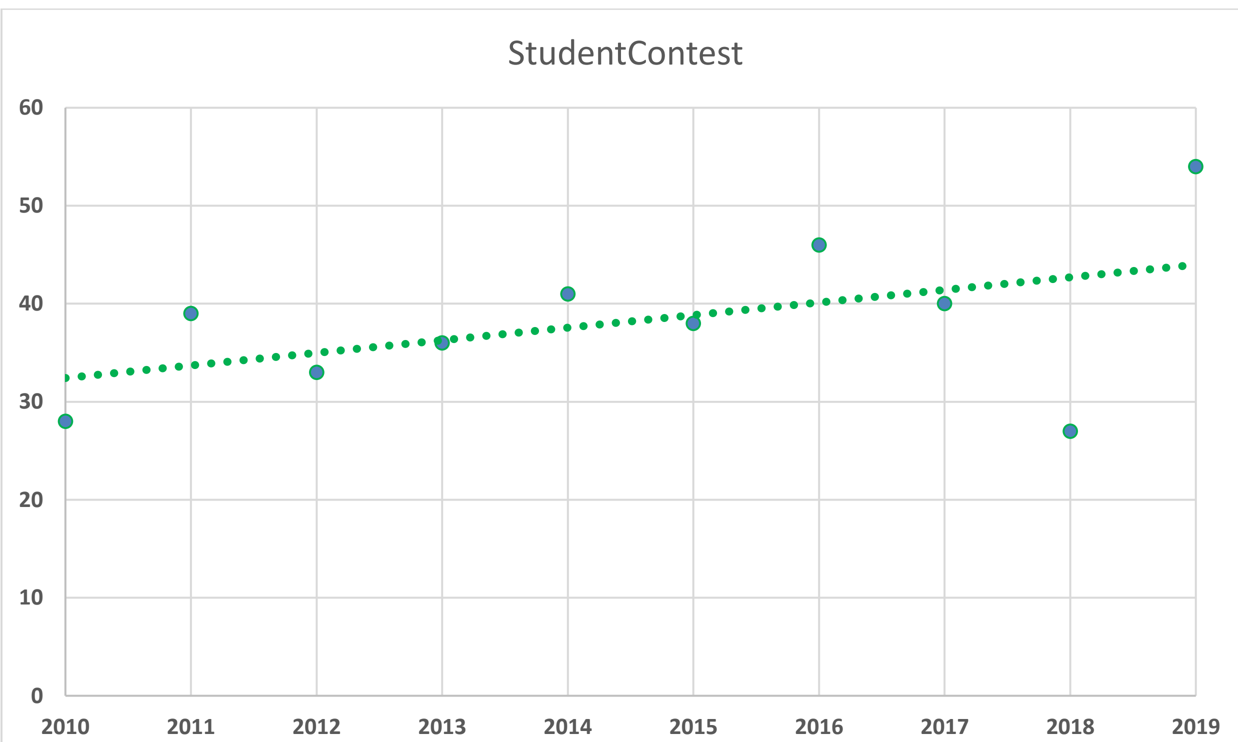
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Thank you:

- Local Arrangements
  Sandra McDonald
- Business Manger
  Eric Gustafson
- Program Committee
  Brad Hanson & Brian Schutte
- Project Chairs

Presidential Address. Andrew Kniss*, University of Wyoming, Lararmie, WY (173)

As I prepared for this Presidential Address, I read many of the previous talks given by previous presidents that are archived in the WSWS proceedings. The types of talks given range widely in their messages and topics: some served as history lessons, some gave personal messages to the membership, some offered advice, some were concise status reports. Nearly all of them were worth reading. I would encourage the membership of WSWS to read through some of these archived speeches, as they provide a window into our society's past challenges and opportunities. One previous presidential address that I distinctly remember hearing was given by Dan Ball, past president from Oregon State University. As I read that address in the proceedings, I was struck by something I didn't remember hearing at the time; it was some advice given to Dr. Ball by his new colleague, Dr. Andy Hulting (now one of our more seasoned society members). As President Ball considered taking a more philosophical approach to his address, Dr. Hulting said "why not go for it, it might be one of your only chances to do that." So Andy, although it was not given to me, I am also going to take your advice.

One common theme that I found in many previous WSWS Presidential Addresses is that we are a welcoming society. Dr. Kassim Al-Khatib in 2007 wrote "We have always been an inclusive not exclusive society." Dr. Roger Gast in 2014 wrote that "The thing that really made me want to stay involved is the welcoming atmosphere we create." Dr. Drew Lyon in 2015 wrote "I know of no other professional society that is as welcoming and friendly as the WSWS." I, too, have found this to be true. The WSWS has been very kind to me, it has offered me many opportunities, and I think the people that attend are gracious and welcoming.

In preparing this address, I tried to reflect on why this might be – *why is the WSWS so darn nice*? One potential explanation is that our membership has so many shared experiences. If you'll endulge me, I'd like to take a moment to describe some of my experiences to make this point.

I grew up on an irrigated farm in the panhandle of Nebraska. My grandma & grandpa, my aunt & uncle, and my mom & dad all farmed together, and all three families lived within 1 mile of each other. I grew up farming the same land that my grandparents farmed while raising my dad & his siblings. Similar to most farm kids, I had many weed-related experiences growing up – hoeing weeds (especially volunteer corn) out of dry bean and sugar beet fields, spraying weeds, and even one particularly unpleasant experience pulling nightshade berries out of pinto bean windrows. I didn't know it at the time, but I even ate quite a few weeds growing up. It turns out that what I knew as 'blackberries' are actually black nightshade (*Solanum nigrum*) berries, that my family and many others in our community would use to make dumplings, pies, jellies, and other recipes.

When I left the farm, I went to two land-grant universities (University of Wyoming & University of Nebraska-Lincoln) to learn about weed science. During my time as a graduate student and years as an early career scientist, I was mentored by some excellent weed scientists, who were also members of the WSWS – Steve Miller, Bob Wilson, Drew Lyon, Mark Farrell, Phil Westra, Scott Nissen, Stephen Enloe, and others.

I suspect that if asked, most members of the WSWS who feel it is a welcoming society have very similar stories in many ways. I suspect that many of us grew up on farms or ranches; many of us attended land-grant institutions; many of us had advisors who were WSWS members or members of other regional weed science societies; many of our current colleagues and mentors are WSWS members. With so many shared experiences, it is no wonder that so many of us seem to 'fit in' and feel welcomed by this society. But this begs the question: to really determine whether our society is, in fact, welcoming and inclusive, is our current membership the appropriate population to survey?

There is a fantastic story about 'survivorship bias' that should be taught in every statistics class. It is a story of damage to WW2 planes that returned from bombing missions. The very brief version of this story is that a group of very smart people were called in to analyze the damage patterns on planes, with the objective of recommending where additional armor should be placed on the planes to protect them. The answer determined by this group of very smart people was counter-intuitive – additional armor should be placed where there was **no damage** to the planes that returned. The reasoning was that if a plane returned, the damage it sustained was tolerable, and therefore no additional armor was needed. The sample they analyzed was missing critically important information: *where was the damage on the planes that did not return?* Presumably, if the cockpit or engine sustained major damage, those planes did not survive. So that is where the armor should be placed.

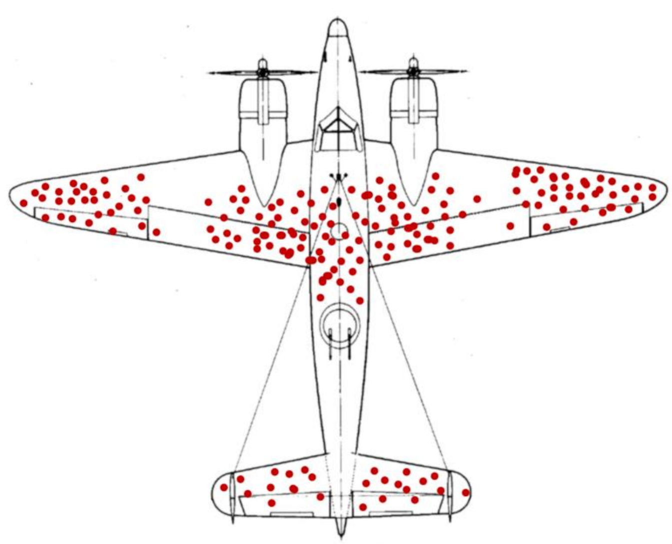

Figure 1. Illustration of a hypothetical damage pattern on a WW2 plane, dot pattern roughly based on pattern credited to Cameron Moll. This image is licenced under the Creative Commons Attribution-Share Alike 4.0 International license. Original file URL: [WW2 Plane Damage]

With the concept of survivor bias in mind, I'd like to now return to the title I've chosen – *Growing Weed Science in the West* – because it deserves some scrutiny. It is not a forgone conclusion that weed science in the West – and in particular, the Western Society of Weed Science – *needs* to grow. I think one could make a strong argument that our society, and perhaps our discipline, is stable and there is no compelling need for growth, at least with respect to membership or attendance. One could argue that we already have 'enough' members, and we have 'enough' participants at our annual meeting. Perhaps there are already 'enough' presentations at our meetings, and we receive 'enough' membership dues to meet our needs and we are training 'enough' students in weed science to meet the demands of our industry. All of these things could be true.

When I suggest that we should grow weed science in the West, I am not necessarily talking about numbers. I believe that any scientific discipline must continue to grow by continually expanding the ideas we generate, and the interesting questions we ask, and the types of solutions that we are proposing. And if we want to grow weed science, we must look beyond who we currently are. We must grow by *actively* recruiting and welcoming a different set of backgrounds and experiences.

As weed scientists, we are called to solve complex problems that farmers and land-managers face. In many ways, our shared experiences have prepared us remarkably well for this difficult job. Because of our backgrounds in agriculture and at land-grant universities, we also share many experiences with our stakeholders and our students and our employees and our mentors. Because of our shared background experiences, we understand the problems they face, and the complexity involved in what causes those problems. Because of our shared experiences we understand why that 'one simple trick to fix agriculture' being proposed by a pundit or an activist isn't simple, isn't a trick, and won't actually fix much of anything. Our shared backgrounds and experiences are extremely valuable.

But solving the complex problems our discipline faces, to use a cliché, will require '*out of the box*' thinking. The best way to find unconventional ideas and solutions is to think about the problem in unconventional ways. That can be difficult for me. My experiences in weed science are, well, *conventional*. There are times when I simply don't know what I don't know. A potential solution to the problem at hand may be relatively simple, but also far enough outside my experiences and background that I may never figure it out. It is important to recognize that when our experiences and knowledge and backgrounds are similar, it is important to seek out people who think differently. Solutions to complex problems are almost never the result of a lone "genius" figuring it all out; rather, great ideas typically originate with great teams, or even great adversaries. The ability of a group of people to think differently and unconventionally about problems (and potential solutions) is quite often a function of the background experiences that group has ***not*** shared.

So yes, I believe we must grow weed science in the West. We must grow the Western Society of Weed Science. Continued growth is necessary to solve the complex problems we face. And we will achieve that growth by being actively inclusive and welcoming to people who are not currently part of our society. We must reach out to a new set of students and scientists. We must find members whose backgrounds do not mirror our own. We must find those botanists and biologists and engineers and ecologists and social scientists and chemists who may not even be aware that ‘weed science’ is a thing. We need to welcome them into our discipline and into our society so they feel every bit as welcome as we do. We need to show them why the problems we are trying to solve are so challenging and interesting. And we must listen to their ideas about how we might address those problems. And this is how we will grow our society into the best society we can be.

I’d like to end my Presidential Address with some very brief words of advice that I was given by my Grandma, Alvina Kniss, when I was attending graduate school. I think this advice is relevant to almost every aspect of life, but particularly relevant to these meetings.

“*Do your very best. Time spent learning is never wasted.*”

Thank you all for coming to the 72nd meeting of the WSWS in Denver. Please go do your very best and spend some time learning.

Discovering Weed Science Possibilities for a More Inclusive Society. Elizabeth Mosqueda*, University of Wyoming, Lararmie, WY (174)

WSWS implemented a Diversity and Inclusion Committee in 2018 because the society recognized the importance of having greater representation within WSWS, the importance of empowering every single one its members, and recognizing this shift as fundamental for our success. As a graduate student in this great society, I thought about how I can do my part when it comes to diversity and inclusion. That’s when I thought, how about trying a bottom up approach. Opposed to recruiting more professionals into our society, perhaps increasing our visibility to more underrepresented undergraduate and graduate students could help with these efforts.

The Society for Advancement of Chicanos/Hispanics & Native Americans in Science (SACNAS) is the United States largest diversity in STEM society whose mission is to foster the success of underrepresented minorities to attain advanced degrees and obtain leadership positions within STEM fields. I brought up the idea to WSWS board early 2018 to exhibit at this meeting and spread the word about our society and weed science, who thought it would be excellent for our society to participate! WSWS sent me and President of the society at the time, Andrew Kniss, to San Antonio TX, October 11-13, 2018 to exhibit at this meeting.

SACNAS-National Diversity in STEM meeting was held for three days and attendees totaled 4,213, of which comprised mostly of undergraduate, professionals, and graduate students. This meeting also closed sessions for a couple hours each day to ensure attendees had time to visit the exhibitor hall. For three days, we were able to highlight our society and the existing opportunities available in the field of weed science to a variety of students and professionals from many different backgrounds. We made contact with over 200 students which we kept track of using business cards that we passed out with our society’s logo and websites leading to our society’s main page and available careers.

The main takeaways from participating in this meeting included finding out that many students do not know that weed science is a profession they can choose if interested in plant/life sciences, but after being told about it, many were interested. This lets us know that we need to increase outreach efforts and make information regarding careers in weed science more accessible. Another key takeaway from exhibiting in this meeting was finding out that Agriculture and Plant Sciences in general are grossly underrepresented at this meeting. Out of 1,169 exhibitors, only four (including WSWS) related to agricultural/plant sciences. These findings allow our society to begin paving the way in becoming a more inclusive and accessible society for all students and professionals and give us a strong foundation for future endeavors related to diversity and inclusion. Therefore, I challenge each member within WSWS to foster attitudes of openness in their place of work, promote diversity in leadership positons, and to speak up about these issues if ever they believe they should.

Washington Update. Lee V. Van Wychen*; Weed Science Society of America, Alexandria, VA (175)

Executive Director of Science Policy Report

WSWS Annual Meeting. Denver, CO, March 12, 2018

2018 Farm Bill Signed into Law in December: Some highlights/lowlights:

- Yes to reauthorization for the Foundation for Food and Agriculture Research (FFAR) at $185M
- No legislative fix for the duplicative National Pollutant Discharge Elimination System (NPDES) program permits
- No Congressional repeal of the 2015 Waters of the United States (WOTUS) rule
- No to legislative guidance to streamline the FIFRA-Endangered Species Act consultation process, but YES to the creation of FIFRA Interagency Workgroup composed of reps from USDA, Interior, Commerce, EPA and CEQ.
- No reauthorization of the Pesticide Registration Improvement Act (PRIA). Note: PRIA 4 was passed by the House and Senate last week and is expected to be signed into law by the President this week.
- Yes to addition of ag research grants for equipment (up to $500K).
- Yes to the use of "Categorical Exclusions" by the Forest Service and BLM for invasive weed control for the purpose of Sage Grouse and Mule Deer habitat restoration
- Yes to legalization of the commercial cultivation and sale of hemp, plus $2M/yr for hemp research.
- No to State Lead Agencies on FIFRA authority over local jurisdictions
- Yes to a new $50M/yr program called the Agriculture Advanced Research and Development Authority (AGARDA). Among its goals is a directive "to undertake advanced research and development in areas in which industry by itself is not likely to do so because of the technological or financial uncertainty". It will have its own director within USDA.

EPA Re-Registers Dicamba Through 2020: On Oct. 31, EPA extended the registration for two years for over-the-top use of dicamba in dicamba-tolerant cotton and soybean. The registration will automatically expire on December 20, 2020, unless EPA further extends the registration. Click **HERE** for details. 2019 – 2020 Dicamba Product labels: **Xtendimax with Vaporgrip** (Updated since Nov. 1, 2018), **Engenia**, & **Fexapan**. **Dicamba federal register documents**: Under "Supporting Documents" there are two documents: 1) Dicamba Pesticide Use Limitation Areas - County list; and 2) The Scientific Basis for Understanding the Off-Target Movement Potential of Xtendimax, which is a 46 pg document from Monsanto that tries to explain why (a) vapor drift occurring due to volatilization should not result in impacts off the treated field; and (b) spray drift will not occur past the label's required buffer distances in amounts that would have an adverse effect on plant height. Also, under the "Comments Section", there is a post from Oct. 31, 2018 titled "Dicamba 2018 Comments", which is 553 pages of documents that EPA received from stakeholders asking them to re-reregister, not re-register, etc. Pages 293-550 are just 1,000s of opposition signatures from the Pesticide Action Network (PAN) and Center for Biological Diversity (CBD). Discussion of the FIFRA Section 24(c) process. States have used the Section 24(c) process to get both emergency uses of pesticides and to pass more restrictive state regulations of certain pesticides. However, there has been political pressure to roll back the Section 24(c) process to its original intent of allowing states only to secure emergency use exemptions of pesticides, but not to allow states to use the Section 24 (c) process to restrict the use of pesticides (i.e. dicamba). States can still be more restrictive of the federal label, but this takes time and money. Dicamba Lawsuit Dismissed but Door Still Open. The 9th Circuit Court of Appeals dismissed a lawsuit against dicamba on Jan. 10, but left open a door for the plaintiffs to expedite a new lawsuit in 2019. The original lawsuit, which was filed by four environmental groups in 2017, argued that the EPA's 2016 registration of XtendiMax for over-the-top use on soybean and cotton fields was unlawful. When that registration ended and EPA renewed the dicamba registration on Oct. 31, 2018, Monsanto and EPA argued that the court should dismiss the lawsuit as moot. The court agreed, but the panel of judges also ruled that the plaintiffs, National Family Farm Coalition et al., should be allowed to fast-track a new lawsuit based on the new 2018 dicamba registration.

Glyphosate: the WSSA Public Awareness Committee is working on a Fact Sheet on glyphosate safety and non-carcinogenicity. The WSSA Board has expressed concern that were not toxicologists or epidemiologists, so we will need to go back to the drawing board.

Atrazine: Ongoing registration review. Human health risk assessment comments were due Nov. 23. We will continue to work with the EPA to refine their environmental risk assessment.

Weed Genomics: There is a strong interest in funding for weed genomics work at USDA NIFA. For example, a better understanding of dioecy in certain weed species such as Palmer amaranth and waterhemp could lead to a NOVEL weed control approach in which a gene drive is used to manipulate gender ratios and drive the population to extinction, similar to the sterile insect technique used to eradicate the screwworm from the U.S. Pat Tranel, University of Illinois, will present a seminar to House and Senate Ag Committee staff on this concept on June 10.

New USDA NIFA Director: Dr. J. Scott Angle began his 6 yr term as NIFA Director on Oct. 29. He worked for 24 years as a professor of soil science and administrator for the Maryland Agricultural Experiment Station and Maryland Cooperative Extension.

Hutchins Re-nominated for USDA Chief Scientist Spot: Dr. Scott Hutchins cleared his Senate nomination hearing on Nov. 28, 2018, but when the 115th Congress expired on Jan. 3 and the 116th Congress began, Hutchins will have to go through the nomination process again. In the meantime, Sec. Perdue temporarily appointed him as a "deputy" under secretary which means he can get to work at USDA but will not have all the authorities of a Senate confirmed under secretary. He was the Global Head of Integrated Field Sciences for Corteva.

USDA-ARS: Rosalind James, the National Program Leader (NPL) overseeing weed science moved into a different role on Nov. 23. We expect USDA to hire a new NPL to oversee weed science and definitely want this person to be a weed scientist (and not an entomologist). The USDA-ARS Crop Protection & Quarantine program (~$90M/yr) had a 5 yr review scheduled for Feb. 6, but that has been rescheduled to April 2 due the partial gov't shutdown.

Alexandra Dapolito Dunn Approved for EPA's Top Chemical Safety Spot: Dr. Dunn was approved by the Senate on January 3, 2019 to lead EPA's Office of Chemical Safety and Pollution Prevention (OCSPP). This office oversees the Office of Pesticide Programs (OPP) that conducts the pesticide registration process. She is an environmental lawyer and law professor specializing in water quality issues. Alexandra was the Regional Administrator for EPA Region 1 (Northeast U.S.) and prior to that, served as executive director and general counsel for the Environmental Council of States (ECOS) as well as the Association of Clean Water Administrators.

Clean Bean Team: Carroll Moseley, Jill Schroeder, Heather Curlett (USDA-APHIS), Patsy Laird, Shawn Conley and I have been working to get the message out to commodity groups and farmers on recommended best practices for reducing weed seeds in U.S. soybean exports. Weed seeds are a serious phytosanitary concern and increases in herbicide-resistant weeds may be contributing to more weed seeds in harvested crops. We have a poster on this that has been at all the weed science meetings (including WSWS). Shawn Conley and I also put together a symposium on this topic at the WSSA meeting in New Orleans.

USDA-NIFA Move from DC: In August, USDA announced that NIFA and ERS would be moving from D.C. While the new location for the agencies has yet to be determined, the timeframe for the move is expected to occur by the end of 2019. USDA's announcement of intent to move the agencies has garnered many concerns from the agricultural research community, including WSSA. However, the Science Policy Committee has not reached a consensus on either to support or oppose the move outright. WSSA did submit a letter to USDA Sec. Perdue with some concerns and questions. In October, USDA received 136 "expressions of interest" from various institutions and cities in 35 states to be the new host location for NIFA and ERS. NIFA Director Angle said he expects that to be narrowed down to 4 or 5 locations within a month and that approximately 50 of NIFA's 300 staff would remain in DC.

WSSA Rep for TAG-BCAW: In June, WSSA selected Dr. John Madsen to be WSSA's new rep for the Technical Advisory Group for Biocontrol Agents of Weeds (TAG-BCAW). However, Dr. Madsen was told by USDA-ARS that he cannot serve in this role. The next highest ranking candidate was Dr. Te-ming Paul Tseng, a weed physiologist at Mississippi State University. Paul was offered and has accepted this role. WSSA will re-evaluate on Mar. 1, 2020.

Syncing USDA Plants Database with WSSA Composite Lists of Weeds: At the WSSA Summer Board meeting, there was a motion to adopt the **USDA Plants Database** as the official source of weed nomenclature and taxonomy and discontinue WSSA's Composite List of Weeds. However, there are some issues with the **USDA Plants Database** that need to be resolved first. The **USDA Plants Database** gets 50,000 hits a day off the internet and is undergoing a major overhaul of its infrastructure and search capabilities. It's run by the USDA-NRCS out of Greenville, NC. The goal is for WSSA to work with NRCS Plants Database team to get them to adopt the 3,000 plus "official" weed names on **WSSA's Composite List of Weeds** as the primary common name for that weed species on NRCS's Plants Database. In most cases, they are the same, but notable differences exist. For example, the USDA Plants Database primary common name for Palmer amaranth is 'carelessweed'. For waterhemp, its 'roughfruit amaranth'. For giant foxtail, its 'Japanese bristlegrass'. USDA is willing to work with the weed science community to get these common names of weeds synced up and good progress is being made.

Science Policy Fellow: WSSA has agreed to put forth $15K to fund two graduate students to serve as Science Policy Fellows (SPF) to support the Executive Director of Science Policy (EDSP). An advertisement went out to all the National and Regional Weed Science Societies. We received six outstanding applications and selected two: John Schramski from Michigan State and Halley Summers from Penn State.

Weed Bingo proposal: The WSSA Board agreed to pay $10,040 on our proposal to produce 1,000 copies of "Weed Bingo" produced by **http://lucybingogames.com/custom**. Carroll Moseley and Eric Gustafson have been instrumental in helping me put this together. We are seeking support and input from each of WSSA's affiliated weed science societies: APMS, CWSS, NCWSS, NEWSS, SWSS, and WSWS. We need to select 42 species of weeds (total) and provide photos of each of them, plus provide 40-60 words of descriptive educational background for each species. Initial feedback from each of the societies is due March 18. The draft list of species assigned to the WSWS is: Dalmatian toadflax, downy brome (cheatgrass), Italian ryegrass, kochia, leafy spurge, saltcedar (tamarisk) and yellow nutsedge. The goal is to sell each Weed Bingo game for $14.95 each + S&H, which is the same price as an existing "**Bug Bingo**" game.

"Executive Visits Day" for Weed Science Society Presidents in DC: The presidents from each of the weed science societies (or their representative) will fly to DC from April 1 – 4 to pound the pavement at USDA, EPA, DOI, etc. as well as on Capitol Hill. We will spend April 2 at USDA-ARS for the review of their Crop Protection and Quarantine Program. The main focus on April 3 will be promoting a Federal Job Series for "Weed Science".

National Invasive Species Awareness Week (NISAW): Was February 25 – March 3, 2019. This was the 20th year of national invasive species/weeds events occurring. My co-host and organizer for NISAW is Rick Otis with the Reduced Risk for Invasive Species Coalition (RRISC). We're looking at two additional NISAW events, one in April dealing with policy issues and one in June that will be hands-on in the field awareness. I'm looking to reinvigorate NISAW in 2020.

Wild Spotter: Mapping Invasives in America's Wild Places: A new nationwide citizen science volunteer capacity-building program called Wild Spotter (**https://wildspotter.org**) has been launched that is designed to help locate and map aquatic and terrestrial invasive species in Wilderness Areas, Wild & Scenic Rivers, and other wild places across the 193 million-acre National Forest System. I added WSWS as a "partner" (along with WSSA, APMS, and the other regional weed science societies).

Natural Resources Management Act (S. 47) Will Become Law: The House and Senate passed a federal lands management bill in February that the President is expected to sign it into law this week. Some of the things addressed in the bill include: land conveyances, exchanges, acquisitions, withdrawals, and transfers; wildlife conservation; wildland fire operations; funding for the Land and Water Conservation Fund; and federal reclamation projects. The bill authorizes approximately $3.5 million per year for FY 2019 to FY 2023 for invasive species management, research and outreach efforts in conjunction with wildlife habitat and conservation. Of the $3.5M authorized, not less than 75% should be used for on the ground control and management and not more than 15% should be used for investigations and outreach.

National Survey of Common and Troublesome Weeds: The 2018 survey results for weeds in aquatic and non-crop areas is posted at **http://wssa.net/wssa/weed/surveys/**. (SEE BELOW). The 2019 weed survey will focus on weeds in broadleaf crops, fruits and vegetables. I am working with Debalin Sarangi, a post doc at Texas A&M and Muthu Bagavathiannan to analyze and publish the weed survey data for agronomic crops from 2015 through 2017 in *Weed Science*.

Big Impacts: Why Impactful Reporting Matters and How to do it Better. Sarah Lupis*; Impact Consulting, Fort Collins, CO (176)

Increasingly, researchers, outreach professionals, and leaders in the agriculture and natural resources sectors are called upon to articulate the impact of their programs and activities. Impact statements provide a steady stream of stories that demonstrate the value of projects and programs to stakeholders, funding agencies, clients and the American people. This session will help your organization better answer two critical questions: why does impact reporting matter? *and* How can we do it well?

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

Modeling Risk of High Cheatgrass Cover. Helen R. Sofaer*[1], Catherine S. Jarnevich[2]; [1]U.S. Geological Survey, Fort Collins, CO, [2]USGS, Fort Collins, CO (069)

Invasive plants impact rangeland systems by affecting native plant communities, fire risk, and forage quality. Understanding and predicting where invasive plants are likely to become abundant can guide management strategies. Assessing risk of a problematic invasion – rather than simply the presence of an invader – is especially important for widespread species such as cheatgrass. We are modeling risk of high cheatgrass abundance across the Great Basin by bringing together BLM's AIM data on plant cover with measures of climate, weather, fire history, and land cover. By predicting spatial variation in the risk of abundant cheatgrass and understanding key drivers, we aim to inform decision-making at local and landscape scales.

Modifying Seeding Date of *Pseudoroegneria spicata* (Bluebunch Wheatgrass) During Revegetation to Limit Re-Invasion by *Bromus tectorum* (Downy Brome). Michelle L. Majeski*[1], Stacy Davis[1], Zach Miller[2], Jane Mangold[1]; [1]Montana State University, Bozeman, MT, [2]Montana State University, Corvallis, MT (070)

Bromus tectorum (downy brome) has existed in the western U.S. for over a century. Impacts of its invasion affect biodiversity and ecosystem services, resulting in a loss of livestock forage and altered fire regimes. Best management practices suggest a multiple-method approach to reduce downy brome. A combination of herbicide application and revegetation with desired perennial grasses is one approach for long-term rangeland restoration. Restoration often fails, however, possibly due to a seasonal priority effect where the species that emerges first, typically the winter annual downy brome, gains an advantage over the later-emerging perennial grass. The objective of this study was to test whether we could shift the seasonal priority effect in favor of a native perennial grass *Pseudoroegneria spicata* (bluebunch wheatgrass) over downy brome by modifying seeding date and timing of herbicide application. We drill-seeded on five different dates from fall 2017 to spring 2018 and applied glyphosate herbicide in the fall or spring at two rangeland sites in southwestern Montana. Results from the first summer after seeding indicated that early May seeding resulted in higher bluebunch wheatgrass density (6 plants per linear meter) than fall seeding (1 plant per linear meter). Spring glyphosate application resulted in better control of downy brome and other weedy species than fall application (25% vs. 34% cover, respectively). These results indicate that seeding date and timing of herbicide application can set up a seasonal priority effect where perennial grasses are favored over invasive winter annual grasses, thus improving restoration outcomes.

Data Visualization and Decision Support Tools for Invasive Species Management. Peder S. Engelstad*; Colorado State University, Fort Collins, CO (071)

Maps of modeled habitat suitability contain information that can inform land management actions. However, the distribution and dissemination of this information is often unidirectional, creating a divide between scientist and practitioner. Integrating incremental feedback, expert knowledge, and on-the-ground experience can lead to the development of tools and systems that bridge this divide and drive stakeholder-centered solutions. Here, we present the Invasive Species Habitat Tool (INHABIT), a web application built with R Shiny that displays visual and statistical summaries of habitat suitability models. Visual summaries are georeferenced maps that could be used to guide on-the-ground activities related to where a weed species may be found and graphics depicting the relationship of the species with the environment while statistical summaries include management unit-based risk assessments. The content and functionality of INHABIT are designed to provide practical information leading to enhanced land management actions. Based on comments and suggestions of practitioners, INHABIT is continually evolving to help bridge gap between scientist and practitioners.

Plant Distribution Data Aid Creation of Invasion Susceptibility Models in the Greater Yellowstone Ecosystem. Christie Hubbard Guetling*[1], Lisa C. Jones[1], Don W. Morishita[2], Eva K. Strand[1], Tim Prather[1]; [1]University of Idaho, Moscow, ID, [2]University of Idaho, Kimberly, ID (072)

Plant community susceptibility models within geographic information systems (GIS) can efficiently locate weed populations by directing ground surveys; thus, saving land managers time and money. The Greater Yellowstone Ecosystem encompasses approximately eight million hectares across parts of Idaho, Montana, and Wyoming and is characterized by conifer forests, sagebrush steppes, and a rich flora. This study aims to aid in the Greater Yellowstone Coalition's goal to reduce the impacts of non-native plants on flora and fauna. The objectives of this study were: 1) accurately identify weed occurrence locations, 2) build and extend susceptibility models within GIS using environmental variables associated with known non-native plant locations, and 3) compare and contrast plant species richness and abundance between known hawkweed locations. Documented locations of orange and meadow hawkweed were used to build plant susceptibility models to predict the likelihood of infestations along with environmental variables: remotely sensed multispectral data, precipitation, hillshade, aspect, and slope. Susceptibility models for orange hawkweed and meadow hawkweed predicted 18,400 hectares and 26,100 hectares, respectively, as highly susceptibility (85-100%). Of the 535,000-hectare study area, the orange hawkweed model excluded (0% susceptible) 118,000 hectares and the meadow hawkweed model excluded 79,000 hectares. A susceptibility model for leafy spurge was developed by using signature values from current Idaho models. High susceptibility (85-100%) to leafy spurge was not predicted in the study area and this model excluded 358,000 hectares. Hawkweed plant communities were evaluated with fourteen 20-meter transects. Preliminary assessment of hawkweed plant community composition, using Chi-squared indicator analysis, suggests meadow hawkweed occurs in drier habitats than orange hawkweed.

Mapping Distributions to Inform Search and Control of Priority Invasive Plants. Catherine S. Jarnevich*, Helen Sofaer; USGS, Fort Collins, CO (073)

Invasive plants can impact native plant communities and ecosystem processes such as fire, and predictions of habitat suitability can be use by mangers to inform search and control. Most predictions focus on where invasive plant species may occur are based on presence data. However, understanding and predicting where invasive plants may become abundant, and thus have a greater impact, may be more useful in guiding management strategies. We have modeled habitat suitability for several species of management concern, including bur buttercup, medusahead rye, ventenata, and red brome. We are now modeling where these species may reach relatively high abundance, using locations with estimated cover of at least 10%. We can also visualize differences in climate space between presence locations and abundant locations. This information may help mangers focus search and control efforts in areas where problematic invasive species may reach high abundance on the landscape.

The Good, the Bad, and the Perennial Grasses: Integrated Management of an Invasive Rangeland Perennial Using Herbicide and Targeted Grazing. Kyle N. Race*, Daniel Tekiela, Brian A. Mealor; University of Wyoming, Laramie, WY (074)

Dalmatian toadflax (*Linaria dalmatica*) is an invasive perennial forb listed as a noxious weed in Wyoming. Native to the Dalmatian coast of Croatia, Dalmatian toadflax has the ability to severely degrade rangeland ecosystems by competing with desirable species, replacing them with its unpalatable biomass. Finding an effective management method to combat this species is of utmost importance. A combination of targeted grazing with sheep (*Ovis aries*) in the summer of 2016 and 2017 and the application of the broadleaf herbicide Telar (chlorsulfuron) in the fall of 2017 were evaluated for efficacy and possible synergistic effects on a Dalmatian toadflax infested site at the F.E. Warren Air Force Base in Cheyenne, WY. Grazing did not have an impact on Dalmatian toadflax cover or biomass, and did not increase the efficacy of Telar. Herbicide treatments significantly reduced toadflax cover and biomass offering great control, however, native forbs were severely reduced, leading to a reduction of biodiversity in herbicide treated plots. Perennial grass cover and biomass were significantly increased in all treatments. Initial Dalmatian toadflax density, measured in percent cover, did not have an impact on herbicide and herbicide grazing treatment success, however higher initial density led to a greater post treatment density in grazing and control groups further suggesting that the grazing treatment alone was not sufficient for Dalmatian toadflax control.

Is One Invasive Annual Grass Worse than Another? Jane Mangold*, Stacy Davis, Lisa J. Rew; Montana State University, Bozeman, MT (075)

The impacts of *Bromus tectorum* (downy brome) in range and natural areas are well-documented. More recently other invasive annual grasses (IAG) like *Ventenata dubia* (ventenata) and *Taeniatherum caput-medusae* (medusahead) have been increasing and, in some cases, displacing *B. tectorum*. This suggests that not just *B. tectorum,* but rather a suite of IAG are problematic, but we don't fully understand if different species have similar impacts in range and natural areas. Our objective was to examine how four IAG [*B. tectorum*, *T. caput-medusa*, *V. dubia*, and *Bromus japonicus* (Japanese brome)] affect livestock forage quantity and quality. We visited 13 sites in Montana where each site was primarily infested by one of the four target IAG. At each site, we sampled canopy cover by species along 3, 100 m transects that spanned a range of low to high cover of the target IAG. We also analyzed above ground tissue of the IAG for crude protein, neutral detergent fiber, acid detergent fiber, and silica. We used linear mixed effects models to examine the relationship between IAG and perennial grass cover and analysis of variance to examine forage quality differences among grasses. Perennial grass cover was negatively associated with *B. tectorum* and *V. dubia* but not *T. caput-medusae* or *B. japonicus*. A 1% increase in *B. tectorum* or *V. dubia* cover correlated with a 0.39% ± 0.05% or 0.48% ± 0.08%, respectively, decrease in perennial grass cover. There were no differences in crude protein or acid detergent fiber of the grasses, but neutral detergent fiber was lower for *B. tectorum* and *B. japonicus* compared to the other grasses. Silica values ranged from 2.9 to 9.2% with *B. tectorum* having the lowest silica value and *V. dubia* having the highest value. Our results suggest one IAG may be worse than another, at least when considering impacts to the quantity and quality of forage available for livestock and wildlife.

Extending the Duration of Biennial and Perennial Weed Seedling Control with Indaziflam Tank-Mixes. Shannon L. Clark*[1], James Sebastian[2], Derek J. Sebastian[3], Scott J. Nissen[4]; [1]Colorado State University, Fort Collins, CO, [2]Boulder County Parks and Open Space, Longmont, CO, [3]Bayer CropScience, Fort Collins, CO, [4]Colorado State University, Ft Collins, CO (076)

Broadleaf weed management on rangelands remains a constant challenge faced by land managers. Herbicides often fail to provide long-term control of invasive broadleaves, even when adequate first-year control is achieved, due to weeds reinvading from the soil seedbank. Indaziflam is pre-emergent (PRE) herbicide with activity on both monocots and dicots. Indaziflam can provide 3+ years of winter annual grass control, yet there is limited information regarding the use of this herbicide for PRE control of broadleaf weeds on rangeland sites. A field study was conducted to evaluate the performance of broadleaf herbicides, picloram and aminocyclopyrachlor, applied with and without indaziflam to control three broadleaf weed species. Nine herbicide treatments and one nontreated control were applied with a tractor boom sprayer to 0.8-hectare plots at two sites in March 2016. Brome, perennial grass, and forb biomass along with species richness and percent cover by weed species were collected 1 and 2 years after treatment (YAT). Every herbicide treatment reduced broadleaf weed cover 1 YAT, while only treatment combinations which included indaziflam continued to control all three species 2 YAT. Increases in cool-season grass biomass occurred at both sites among treatments which included picloram plus indaziflam, while warm-season grass increases occurred in treatments containing aminocyclopyrachlor plus indaziflam. At 2 YAT, indaziflam treatments had greater species richness (12.3 species) compared to the nontreated (4.8 species). Using indaziflam in combination with broadleaf herbicides has the potential to provide multi-season weed control by managing the seedbank of both grass and broadleaf weeds, possibly allowing enough time for the release of the native plant community.

Restoration of Western Natural Areas and Rangeland - Depleting the Invasive Annual Grass Seed Bank. Harry Quicke*[1], Derek J. Sebastian[2]; [1]Bayer CropScience, Windsor, CO, [2]Bayer CropScience, Fort Collins, CO (077)

Western natural areas and rangeland are undergoing constant degradation through invasion of annual grasses such as downy brome (cheatgrass), ventenata and medusahead. In addition to direct competition for resources, these grasses provide the fine fuel that allows for an increase in the frequency and size of wild fires. In addition to societal disruption and health effects from smoke, the increased fire frequency can eliminate desirable perennial grass, forb and shrub species. There is an urgent need to slow the spread of invasive annual grasses and to restore degraded areas. Trials across the west document that a single application of indaziflam herbicide provides multiple years of annual grass control, providing a new opportunity to start depleting the annual grass seed bank. Remnant desirable perennial species respond quickly to removal of the annual grass component.

Response of Wildlife Browse Species to Invasive Winter Annual Grass Control with Indaziflam. James Sebastian*[1], Joseph K. Swanson[2], Steve Sauer[1], Derek J. Sebastian[3]; [1]Boulder County Parks and Open Space, Longmont, CO, [2]Boulder County Parks and Open Space, Erie, CO, [3]Bayer CropScience, Fort Collins, CO (078)

Native shrub, brush, and forb species on rangeland are losing ground to cheatgrass (downy brome (Bromus tectorum L.) and Japanese bromes (Bromus japonicus Thunb.), and other invasive winter annual grasses at an alarming rate throughout the Western United States. Cheatgrass establishes in the fall and winter, robbing moisture and nutrients from the soil when native grasses and forbs are still dormant. These winter annuals reproduce quickly and out compete native vegetation. By July, cheatgrass has totally dried out and poses extreme fire hazard. Downy brome produces fine fuels which increases fire frequency and alters vegetation composition. Unlike the more-isolated native bunchgrasses, cheatgrass creates a continuous cover of highly flammable fuel. Areas that were once sparsely vegetated and fire-resistant with native species are now dense, dry tinderboxes. When ignited, wildfires spread through downy brome-dominated landscapes quickly and completely, consuming much larger areas.

Cheatgrass invasion has done more than just increase the acreage burned annually in the West. It has also dramatically changed fire frequency. The increase in fire frequency has reduced desirable shrubs, brush, and forb species essential to mule deer and other wildlife. As a result, the native plant communities that support mule deer herds are decreasing at an alarming rate. In cheatgrass ranges, fires occur every 10 years or less. Before cheatgrass invaded, fires occurred every 30–75 years. Increased fine fuels also change the intensity and rate at which fires burn, resulting in monoculture plant communities. Fuel loads build up such that when infrequent fires occur, they cover large regions and burn very hot. Hot, catastrophic fires contribute to soil erosion and prevent regeneration of brush, shrub, and other native species.

The mule deer population throughout the Western US is particularly limited by the amount of food available on winter ranges. Native shrub and brush species are critical on Western winter ranges. In the absence of natural wildfires, decade-old plants have increased in density, greatly increasing the risk of catastrophic wildfires. Some of these large, older plants are necessary to provide cover for wintering mule deer, sage grouse and other wildlife but offer low nutritional value.

Although cheatgrass may be used as forage by livestock and wildlife, it is not be preferred. During the winter deer survive by feeding on browse species. Mule deer browse the leaf or twig growth of shrubs, woody vines or trees. Examples of commonly eaten shrubs and browse include sagebrush, bitterbrush, mountain mahogany, cliffrose, rabbitbrush, winterfat, scrub oak, serviceberry, and willow. In the summer, mule deer continue eating a combination of grasses and forbs. The condition and availability of summer and fall forage is critical. In late summer, as the grasses and flowering plants dry out, mule deer shift their diet back to shrubs and brush species.

There are limited management options for consistently controlling winter annual grasses, provide multiple years of control, and do not injure desirable plant communities. Imazapic has been one of the most-widely used herbicides on rangeland, but this herbicide lacks consistency beyond the year of application and can cause injury to perennial grasses. Indaziflam, a new herbicide mode of action for rangeland weed management, has provided long-term residual winter annual grass control in several field experiments.

Boulder County Open Space (BCOS) manages over 200,000 acres of scattered properties in the lowland, foothills and mountains of Colorado. Several of the properties include critical winter habitat with high native forb, shrub, and grass diversity that benefits muledeer, elk, and other wildlife. One concern of BCOS ecologists and wildlife biologists is the loss of native forbs, shrub, and brush species in these critical wildlife habitat areas. Although tree thinning and prescribed burns have been implemented to restore the health of native vegetation in these areas, high intensity burns in areas with dense monotypic stands of cheatgrass have complicated the recovery process. Cheatgrass continues to increase and critical winter browse has decreased in quality and density on these properties. To combat this problem, BCOS has with plants that will reduce the intensity and frequency of future fires.

BCOS has worked in cooperation with CSU to determine effective long-term control of downy brome that reduces the intensity and frequency of future fires and promotes flowering native forb, shrub, and brush species that benefit mule deer, elk, pollinators, and other wildlife. In an effort to combat this problem along the Front Range in Colorado and the Western US, BCOS has taken a lead role in figuring out a strategy for long term control of downy brome and other invasive winter annuals to release native species that benefit pollinators, big game habitat, and other wildlife species. In winter 2017 and 2018 six sites were sprayed with indaziflam plus glyphosate. These sites were 2 to 5 acres in size with relatively dense stands of mountain mahogany, 4 lobed sumac, antelope bitterbrush, winterfat, rubber rabbitbrush, four-winged saltbrush, and fringed sage. Each site was sprayed with a John Deere 6420 tractor, 24' boom, 40 psi, and 30 gallons of water/acre. The applications were made in winter after all brush leaves had dried and fallen off for the winter (winter dormancy). Dormant treatments were chosen to spray tall, dense stands of brush and shrubs when no leaves were present to assure quicker and better penetration of the application to penetrate and activitation with winter moisture through the thick canopy for controlling downy brome. 3 permanent 200' transects were created inside areas sprayed and 3 transects immediately adjacent to areas that were not sprayed to monitor native brush and shrub growth (longest stem, height, diameter, and scar height). Cheatgrass and native forb, shrub, brush, and grass species canopy cover was also collected via line intercept on the same 200' transects. Weed and native species biomass was collected and separated by species on 10 x 1 meter quadrats. Cheatgrass litter biomass was collected in each of the 10 quadrats to determine fine fuel weights in areas sprayed vs non-sprayed areas. Fine fuel biomass would provide an indication on how quickly litter degrades on the soil surface at the 6 sites.

All brush and shrub species longest leader growth nearly doubled in length for all species in sprayed vs non-sprayed plots. Three key browse species on BCOS properties (mountain mahogany, bitterbrush, and rabbitbrush) had 6 to 12" vs 15 to 28" long leaders in check vs Esplanade treated areas. It was evident that cheatgrass competes directly with shrub and brush species for moisture and significantly reduced new growth growth at all sites. Native grass cover increased 2 to 3x in sprayed areas. There was 7 to 36% perennial grass cover in checks and 36 to 56% native perennial grass cover in sprayed blocks. There was 100% cheatgrass control with indaziflam plus glyphosate at all sites (0% cheatgrass canopy cover in sprayed vs 85 to 100% cheatgrass cover in nontreated areas). Cheatgrass fine fuels (litter) decomposed extremely fast at all of these sites. Cheatgrass fine fuel litter averaged 899 lb/A in untreated sites and 120 lb/A at sites that were sprayed approximately 6 months prior to harvesting litter. The three sites that were sprayed approximately 24 months prior to evaluations had 0 lb/A cheatgrass litter remaining and fine fuels were eliminated. There has been no visible shrub or brush species injury from indaziflam plus glyphosate treatments sprayed when dormant at these or any other BCOS sites.

Although it's too early to tell, but BCOS is already observing positive strides towards effective long-term control of cheatgrass that will potentially reduce the intensity and frequency of future fires. These in turn will promote flowering native forb, shrub, and brush species that benefit mule deer, elk, pollinators, and other wildlife.

Large Scale Control of Invasive Weeds and Response of Native Species Using Indaziflam on Boulder County Open Space Properties. Steve Sauer*[1], James Sebastian[1], Joseph K. Swanson[2], Derek J. Sebastian[3]; [1]Boulder County Parks and Open Space, Longmont, CO, [2]Boulder County Parks and Open Space, Erie, CO, [3]Bayer CropScience, Fort Collins, CO (079)

Boulder County Parks & Open Space is one of the largest open space programs in the nation, covering over 105,000 acres. This area includes agricultural production, rangeland and forested lands in Boulder County. Invasive species management on non-crop and rangeland remains a constant challenge throughout many region of the U.S. While there are over 300 rangeland weeds, downy brome (Bromus tectorum), Dalmatian toadflax (Linaria dalmatica), musk thistle (Carduus nutans), Canada thistle (Cirsium arvense), diffuse knapweed (Centaurea diffusa), and moth mullein (Verbascum blattaria) have emerged as the most invasive and problematic on Boulder County Open Space properties. Espanade (Esplanade 200 SC Bayer Crop Science) has been adopted by many land manager throughout Colorado with an open space and natural areas label. Esplanade and all Esplanade tank mixes resulted in 100% downy brome control the first growing season after treatment and all tank-mix combinations with Esplanade provide an increase in weed control as compared to treatments without Esplanade. Esplanade did not injure native grasses or forbs, resulting in a significant increase in species richness compared to the non-treated control. In addition to a large scale CSU research plot, over 1500 acres were sprayed with Esplanade and Esplanade tank mixes on 78 different sites between the spring of 2016 and spring of 2018 on Boulder County Open Space property. These were monitored for canopy cover and weed control in June 2018. There were dramatic increases in native response to the release of invasive weed competition. 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 U.S.

Indaziflam Effects on Seed Production of Established Perennial Grasses. Beth Fowers*[1], Brian A. Mealor[2]; [1]University of Wyoming, Sheridan, WY, [2]University of Wyoming, Laramie, WY (080)

Annual weeds, like cheatgrass (*Bromus tectorum* L.), negatively impact grass seed production by directly competing for resources and contaminating seed lots. Herbicide options in grasses grown for seed are relatively limited, and for one to be useful it must provide acceptable weed control with little reduction in seed production and viability. Indaziflam controls annual grasses and other weeds, but we know little about how it affects seed production and germinability. Our objective was to evaluate the effects of indaziflam on grass seed production and germinability across a range of plant materials. Thirteen different grass species (or varieties) were seeded in a randomized complete block design with four replicates at Wyarno, WY in 2013. We applied indaziflam (73 g ai·ha^{-1}) and glyphosate (420 g ai·ha^{-1}) to one half of each plot on March 27, 2017. Cheatgrass was actively growing and some of the perennial grasses had broken dormancy at the time of application. We harvested, counted, and weighed mature inflorescences early July 2017 and mid to late July 2018 from three bunchgrasses per plot or from within a 0.25 m^2 frame for rhizomatous grasses. We evaluated cumulative germination using 50-seed lots in petri dishes with filter paper in a growth chamber set at 21° C daytime and 10° C nighttime temperatures for one month. We analyzed data as a two-way ANOVA with plant material and herbicide as the two treatments. Two years after herbicide application, indaziflam provided nearly 100% cheatgrass control. Herbicide treatment affected seed production ($p<0.001$) in 2017 and 2018, though directionality and magnitude of effects varied among species and across years. While our experimental design prevents us from directly separating first year glyphosate effects from indaziflam, the lack of negative impacts in 2018 suggest glyphosate may have affected germinability in 2017. Our findings suggest indaziflam provides acceptable annual weed control in desirable rangeland grasses grown for seed production, if appropriate labeling is approved.

GF-3850, a New Herbicide for Use in Rangeland, Pastures and Other Non-Crop Sites. William Hatler*[1], Byron Sleugh[2], Pat Burch[3], Scott Flynn[4], Daniel C. Cummings[5], Charles Hart[6]; [1]Corteva Agriscience, Meridian, ID, [2]Corteva Agriscience, Indianapolis, IN, [3]Corteva Agriscience, Christianburg, VA, [4]Corteva Agriscience, Lees Summit, MO, [5]Corteva Agriscience, Bonham, TX, [6]Corteva Agriscience, Abilene, TX (141)

GF-3850 is a new herbicide developed by Corteva Agriscience™, Agriculture Division of DowDuPont, for managing noxious and invasive plants in rangeland, pasture, rights-of-way, and other non-cropland sites. GF-3850 controls over 100 susceptible herbaceous broadleaf plants including yellow starthistle (*Centaurea solstitialis*), Canada thistle (*Cirsium arvense*), musk thistle (*Carduus nutans*), wild carrot (*Daucus carota),* Horse nettle (*Solanum carolinense*), Purple loosestrife (*Lythrum salicaria*), silverleaf nightshade (*Solanum elaeagnifolium*), squarrose knapweed (*Centaurea squarrosa*), spotted knapweed (*Centaurea maculosa*), and poison hemlock (*Conium maculatum*). Research trials were initiated in 2015 on rangeland, pasture, and non-cropland sites to assess the efficacy of GF-3850 on noxious and invasive weeds and weeds that negatively impact forage-livestock productivity or wildlife habitats. In these experiments GF-3850 at 75 to 126 g active ingredient ha^{-1} was applied with CO_2-pressurized backpack sprayers in spray volumes of 10 to 20 GPA. Percent visual control assessments were made and are reported for a selected number of species. GF-3850 provided excellent control of these noxious and invasive species with low use rates compared to some products currently used for this purpose. GF-3850 will control all the weeds currently controlled by Milestone® herbicide and many additional species. Based on these efficacy data, GF-3850 will be a useful tool in the management of these difficult to control noxious and invasive weeds in rangeland, pastures, rights-of-way, and other non-crop sites.

GF-3886, a New Herbicide for Use in Non-Crop Sites, Rangeland and Pastures. Daniel C. Cummings*[1], Byron Sleugh[2], Pat Burch[3], Scott Flynn[4], William Hatler[5], Charles Hart[6]; [1]Corteva Agriscience, Bonham, TX, [2]Corteva Agriscience, Indianapolis, IN, [3]Corteva Agriscience, Christianburg, VA, [4]Corteva Agriscience, Lees Summit, MO, [5]Corteva Agriscience, Meridian, ID, [6]Corteva Agriscience, Abilene, TX (142)

GF-3886 is a new herbicide developed by Corteva Agriscience™, Agriculture Division of DowDuPont, for control of broadleaf weeds, including invasive and noxious weeds, and certain woody plants. GF-3886 represents an innovative new tool that is a non-ester, non 2,4-D containing, low odor, low use rate formulation that provides post emergence and reemergence residual control of susceptible broadleaf plants and seedlings and some woody plants. It will provide control of all species known to be controlled by Milestone® herbicide plus many additional species and offers flexibility in application (ground, aerial, broadcast, or spot treatment). A key component of GF-3886 is Rinskor™ active, a novel new active ingredient never before used rangeland and pastures and is an EPA Reduced Risk Pesticide just like Milestone. In trials over multiple years across the United States, GF-3886 provided excellent control of weeds such as yellow starthistle (*Centaurea* *solstitialis*), Canada thistle (*Cirsium arvense*), musk thistle (*Carduus nutans*), wild carrot (*Daucus carota),*Purple loosestrife (*Lythrum salicaria*), silverleaf nightshade (*Solanum elaeagnifolium*), squarrose knapweed (*Centaurea squarrosa*), spotted knapweed (*Centaurea maculosa*), poison hemlock (*Conium maculatum*), woolly croton (*Croton capitatus*), annual marshelder (*Iva annua*), common broomweed (*Gutierrezia dracunculoides*), common caraway (*Carum carvi*), and many more. Based on these efficacy data, it is anticipated that GF-3886 will be a useful tool in the management of noxious, invasive and other weeds in various sites.

Total Vegetation Management: A Comprehensive Summary of Herbicides, Application Timings, and Resistance Management Options. Scott J. Nissen*[1], Derek J. Sebastian[2], Shannon L. Clark[3], Dwight K. Lauer[4]; [1]Colorado State University, Ft Collins, CO, [2]Bayer CropScience, Fort Collins, CO, [3]Colorado State University, Fort Collins, CO, [4]Silvics Analytic, Wingate, NC (143)

Total vegetation management, sometimes referred to as bare ground (BG), is an important component for the safe operation of railroads, power substations, oil and gas facilities, or any instillation where vegetation could pose a fire risk or visibility hazard. Railroad weed management operations have used a limited number of herbicide combinations to manage vegetation over extensive areas and as a result are often sited as a source for herbicide resistant weed evolution, especially to ALS and PSII inhibiting herbicides. A multi-year/multi-site field experiment was established to compare over 32 treatment combinations to two industry standards for total vegetation management. The objective of this research was to potentially identify newer, lower use rate, less expensive herbicide options for the establishment of BG. The top four herbicide combinations that consistently provided 97 to 100% BG across all sites, application timings, and variable weed spectrums included aminocyclopyrachlor, chlorsulfuron, indaziflam, and imazapyr. The industry standard of diuron plus imazapyr ranked fifth in terms of providing % BG and consistency across multiple sites. With multiple sites over several years it was possible to use probability modeling to determine the probability of achieving 100% or 97% BG with various treatment combination. The same five treatments had the highest probability of achieving BG. The combination of aminocyclopyrachlor, indaziflam, and imazapyr had an 88% probability of achieving 100% BG compared to 61% probability for the industry standard of diuron plus imazapyr. The top four treatments represent newer, lower use rate herbicide combinations that provide more modes of action to manage herbicide resistant weeds.

Presence of *Cytisus scoparius* Modifies Short-Term Productivity of Glacial Outwash Soils in Western Washington. Timothy B. Harrington*[1], Robert A. Slesak[2], Anthony W. Damato[3]; [1]USDA Forest Service, Olympia, WA, [2]University of Minnesota, Minneapolis, MN, [3]University of Vermont, Burlington, VT (144)

Scotch broom (*Cytisus scoparius*) is a large nonnative, leguminous shrub that has invaded 19 eastern and 8 western U.S. states. The species interferes with native plant species via both competition and apparent allelopathy. We conducted a soil bioassay study in a greenhouse to determine if: (1) nutrient amendments eliminate apparent allelopathic responses, (2) allelopathic effects of Scotch-broom-invaded soils decline with time since broom removal, and (3) the size of the Scotch broom seed bank varies with time since broom removal. In early spring 2018, we

collected glacial-outwash soils from different locations within the Matlock, WA Long Term Soil Productivity Study in which broom had been removed or kept out for 0 (broom present), 4, 10, or 14 years. Three native plant species were selected for the bioassay: coast Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*), yarrow (*Achillea millefolium*), and Roemer's fescue (*Festuca roemeri*). Three fertilizer treatments were compared: non-fertilized, P amended, and a complete macro- and micronutrient treatment. The experimental design was a randomized complete block with a factorial arrangement of treatments and five replications per treatment (n=180 pots in total). Bioassay species were germinated in flats, transplanted into 2.3 L pots, grown for 120 days with overhead sprinkler irrigation, and harvested for aboveground biomass. Belowground biomass of Douglas-fir also was determined. Scotch broom germinants were periodically counted and removed to assess seed bank size. Above- and belowground biomass of Douglas-fir did not differ significantly among fertilizer treatments, providing evidence for allelopathic effects from Scotch-broom-invaded soils (study objective #1). Douglas-fir aboveground biomass had a positive linear relationship with years since broom removal, suggesting declining allelopathic effects (study objective #2). Soils from 0 and 4 years since broom removal had over 200,000 viable seeds ha^{-1} of Scotch broom. However, no Scotch broom germinants were found in 10- and 14-year soils likely because the invasion was prevented in these areas (study objective #3). In conclusion, combined effects of allelopathy and competition from Scotch broom compound the challenges to sustaining Douglas-fir productivity on broom-invaded sites. Aggressive early control, soon after detection, will limit the size of a Scotch broom infestation and associated seed bank (note that flowering occurs at age 2-3 years). Long-invaded areas may require 5 years or more of Scotch broom control before allelopathic effects have subsided. Physical removal of Scotch broom biomass may accelerate the decline in its allelopathic effects.

Biotic and Abiotic Indicators of *Ventenata dubia* in Canyon Grasslands. Lisa C. Jones*, Tim Prather; University of Idaho, Moscow, ID (145)

Ventenata (*Ventenata dubia*), a non-indigenous annual grass, is a growing problem in the Pacific Northwest where it significantly reduces forage production in pasture and grassland systems and displaces both perennial and annual dominated grasslands. Currently, there is limited knowledge of what other plants and physical features of the environment are associated with ventenata invasion in canyon grasslands. We collected plant cover data along 45 transects at five sites in northern Idaho to assess biotic characteristics associated with ventenata. We then correlated species richness with no, low (<12.5% foliar cover), and high (>12.5% foliar cover) ventenata cover. In addition, we evaluated landscape features, such as soil depth, aspect, and slope, that may affect ventenata abundance. Across all sites, ventenata was present in 55% of the 225 plots and foliar cover was typically less than 25%. High ventenata cover was correlated with lower species richness. Species rank abundance models showed that as ventenata cover increased, invasive annual brome cover decreased. Chi-squared indicator analysis showed that Japanese brome (*Bromus japonicus*), prairie smoke (*Geum triflorum*), and medusahead (*Taeniatherum caput-medusae*) were positively associated with ventenata; snowberry (*Symphoricarpos albus*), piedmont bedstraw (*Cruciata pedemontana*), and bur chervil (*Anthriscus caucalis*) were negatively associated with ventenata. Abiotic factors that explained variation in ventenata abundance included less rock, more bare ground, shallow soils, gentle slopes, and a south/west aspect. Unlike results from prior studies, there was no correlation between ventenata cover and soil texture or nutrient concentration. Overall, these findings indicate that in canyon grasslands, ventenata is becoming more abundant than invasive annual brome species and high cover is correlated with decreased plant diversity. Lastly, ventenata appears to be less competitive in low shrub communities relative to bunchgrass-dominant communities.

Herbicide Trials with Brazilian Egeria (*Egeria densa*) for Management in the Sacramento / San Joaquin River Delta. John D. Madsen*; USDA-ARS, Davis, CA (146)

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

Spring and Fall Herbicide Applications to Scotch Thistle Rosettes. Thomas J. Getts*; UCCE, Susanville, CA (147)

Scotch thistle (*Onopordum Antcanthium*) is a biennial plant that can be problematic under a variety of rangeland conditions. It is highly invasive and is listed on noxious weed lists in ten western states. Populations of Scotch thistle in Northeastern California are widespread and still expanding under active management. While mechanical control can be utilized on small infestations, herbicides are often chosen for controlling large infestations. In October of 2016, a study was implemented outside of Doyle, California, to investigate applications of various herbicides to provide control of Scotch thistle rosettes. Local research previously had focused on spring applications, where this project investigated both fall (2016) and spring (2017) applications. Treatments were made to 3*6-meter plots with a hand-held CO_2 pressurized backpack sprayer, in a random complete block design. Visual assessment of Scotch thistle control, and the effect on non-target vegetation composition was conducted periodically throughout the 2017 and 2018 growing seasons. Fall applications of aminocyclopyrachlor, aminopyralid, chlorsulfuron and aminocyclopyrachlor + indaziflam provided greater than 90% thistle control throughout the 2017 growing season. In August of 2018, 22 months after fall applications, only chlorsulfuron and aminocyclopyrachlor + indaziflam provided greater than 85% thistle control. Spring applications of aminopyralid and aminocyclopyrachlor gave more than 90% thistle control throughout the 2017 growing season. Sixteen months after treatment in August of 2018, greater than 90% thistle control was still observed for spring applications of aminopyralid and aminocyclopyrachlor. In most treatments, Scotch thistle cover was replaced with large increases in winter annual grass cover. However, applications of aminocyclopyrachlor + indaziflam suppressed winter annual grass populations, resulting in increased cover of perennial grasses, perennial broadleafs and bare ground.

Aminonpyralid + Picloram + Fluroxypyr for Pricklypear Control and Oak Tolerance when Applied by Ground and Aerial Broadcast. James R. Jackson*[1], Robert Lyons[2], Charles Hart[3]; [1]Texas A&M AgriLife Extension, Stephenville, TX, [2]Texas A&M AgriLife Extension, Uvalde, TX, [3]Corteva Agriscience, Abilene, TX (148)

Pricklypear cactus (*Opuntia* spp.) is a native and invasive plant found throughout western and central Texas. Pricklypear spreads rapidly across the landscape limiting forage production and forage access for grazing animals. For years the standard in chemical pricklypear control has been Tordon 22K (picloram) or Surmont (picloram and fluroxypyr). While these herbicides obtain a high level of control for pricklypear they can take a long period of time to visually see any sign of desiccation or sickness on the treated plant. Surmount while it does deliver a high rate of mortality on pricklypear it is also damaging to live oaks *(Quercus virginiana)* which are desirable to many landowners in Texas. In Spring of 2019 Corteva Agrisciences will release their new herbicide MezaVue (picloram, fluroxypyr and aminopyralid) for pricklypear control in Texas, New Mexico and Oklahoma. Prior to MezaVue being released, rate studies were established in 2017 and 2018 to determine what rate provided the most consistent and highest level of pricklypear desiccation when applied by ground broadcast. In 3 ground broadcast trials MezaVue at 32 ounces product per acre delivered an average desiccation rating of 80 percent at 12 months after treatment. Live oak tolerance studies were also established in 2017 and 2018 to determine how MezaVue compared to the current standards for oak tolerance when applied aerial over the trees. When applied by air over live oaks MezaVue did cause visual damage at the time of application, however; at one year after treatment the live oak trees in the MezaVue plots had less damage than live oaks in the Surmount plots.

Florpyrauxifen: A New Arylpicolinate Herbicide for Weed Management in Pastures, Rangeland and Other Non-Crop Sites. Byron Sleugh*[1], Pat Burch[2], Scott Flynn[3], Daniel C. Cummings[4], William Hatler[5], Charles Hart[6]; [1]Corteva Agriscience, Indianapolis, IN, [2]Corteva Agriscience, Christianburg, VA, [3]Corteva Agriscience, Lees Summit, MO, [4]Corteva Agriscience, Bonham, TX, [5]Corteva Agriscience, Meridian, ID, [6]Corteva Agriscience, Abilene, TX (149)

Rinskor™ active is a new herbicide active ingredient from Corteva Agriscience™, Agriculture Division of DowDuPont. It is the second member of a unique synthetic auxin chemotype, the arylpicolinates (HRAC group O / WSSA group 4), and was preceded by Arylex™ active. Members of the arylpicolinate family demonstrate novel and differentiated characteristics in terms of use rate, spectrum, weed symptoms, environmental fate, and molecular interaction as compared to other auxin chemotypes. Rinskor is unique because it binds preferentially to different auxin receptors as compared to other auxin types. Rinskor was a winner of the 2018 Green Chemistry Challenge Award presented by the American Chemical Society's Green Chemistry Institute and has also been designated as a Reduced Risk Pesticide by the Environmental Protection Agency. In addition, Rinskor won the 2018 Agrow Award for Best New Crop Protection Product and was recognized with an R&D 100 Award for Corporate Social Responsibility. Rinskor is registered and is being used in the United States for the control of weeds in rice, and also for selective aquatic weed control. Rinskor, especially in mixtures with other selected herbicides, has differentiated broad spectrum activity and high efficacy against important broadleaf weed species in rangeland, pasture, natural areas, and other non-crop sites. In trials over multiple years and locations of the United States, Rinskor containing mixtures have provided excellent control of weeds such as Canada thistle (*Cirsium arvense*), musk thistle (*Carduus nutans*), wild carrot (*Daucus carota*), poison hemlock (*Conium maculata*), wild parsnip (*Pastinaca sativa*), spotted knapweed (*Centaurea maculos),* silverleaf nightshade (*Solanum elaeagnifolium*), Western ironweed (*Vernonia baldwinii*), horse nettle (*Solanum carolinense*), woolly croton (*Croton capitatus*), annual marshelder (*Iva annua*), common broomweed (*Gutierrezia dracunculoides*), common caraway (*Carum carvi*), and many others. With its many positive attributes, it is anticipated that the availability of Rinskor for use in rangeland, pastures, wildlife habitat areas, natural areas, and vegetation management and other non-crop sites will be a beneficial new tool for land managers.

Unavoidable Collateral Damage, the Reality of Invasive Plant Management. Dan R. Tekiela*; University of Wyoming, Laramie, WY (150)

Much of rangeland and natural area weed management is implemented using small backpack sprayers due to the ruggedness of terrain. Although backpack sprayers allow for highly spatially selective treatments, applying a consistent rate can be difficult even for trained professionals; thus, over application is likely. Over applying herbicide in natural areas may lead to unintended off-target impacts, specifically injuring the surrounding desirable vegetation. This study intends to identify the size of the herbicide rate 'window' between target species control and off-target desirable injury to identify if certain herbicides are less 'sensitive' to over-application. We performed a greenhouse and field study utilizing common herbicides to control Dalmatian toadflax (*Linaria dalmatica*) to determine herbicide sensitivity windows and found that not all herbicides have similar herbicide windows. Greenhouse conditions suggested aminocyclopyrachlor had a greater overall sensitivity window and thus may be the better option with certain surrounding desirable vegetation, while field conditions suggested chlorsulfuron had a greater sensitivity window.

Non-target Impacts from Basal Bark Treatments of *Prunus padus*. Gino Graziano*[1], Steven S. Seefeldt[2], Patrick Tomco[3], Mingchu Zhang[4], Christa Mulder[4]; [1]University of Alaska Fairbanks, Anchorage, AK, [2]Washington State University, Mount Vernon, WA, [3]University of Alaska Anchorage, Anchorage, AK, [4]University of Alaska Fairbanks, Fairbanks, AK (151)

Documented *Prunus padus* invasions in the boreal forest of Alaska are increasing annually, and are no longer isolated to Anchorage and Fairbanks. To control these infestations invasive plant managers need effective treatments that minimize impacts to surrounding vegetation. Off target impacts on vegetation in the root zone of invasive plants that were treated with herbicides applied with either cut stump, frill, or basal bark treatments are occasionally suspected. These treatments are often applied in order to reduce off target impacts. Little attention has been given to the potential for an herbicide to be released from the target plant into the environment. Our hypotheses are that directly applied herbicides could be released to the soil through decomposition of treated plant material, transfer through root to root contact, or leakage from roots. We conducted a study to determine if basal bark treatments of *Prunus padus* with aminopyralid results in off target impacts to sensitive species due to leakage from roots of treated trees. We previously reported results from laboratory trials that indicated aminopyralid residues were present in soils after basal bark treatments. These laboratory trials were coupled with field trials using 1X label rates of aminopyralid, triclopyr, and the combination of aminopyralid and triclopyr. We will present evaluations of efficacy of the field basal bark treatments, and observed non-target impacts which were present on some but not all treatments containing aminopyralid.

PROJECT 2: WEEDS OF HORTICULTURAL CROPS

Herbicide Management in *Solanum sisymbriifolium* a Trap Crop for Pale Cyst Nematode in Potato Systems. Pamela J. Hutchinson*[1], Brent Beulter[2], Celestina S. Miera[3], Brenda C. Kendall[3], Tenika S. Trevino[3]; [1]University of Idaho Aberdeen R&E Center, Aberdeen, ID, [2]University of Idaho, American Falls, ID, [3], Aberdeen, ID (130)

In 2006, pale cyst nematode (PCN) (*Globodera pallida*) was found in soil from an Eastern, ID potato field, and subsequently, in 25 nearby potato-production fields. To date, the Idaho infestation is the only one in the United States. Litchi tomato, *Solanum sisymbriifolium*, (LT) is being developed and effectively used in Idaho as a suicide-hatch, PCN trap crop. A herbicide-management plan for LT is being developed by the University of Idaho, and in 2018, preemergence (PRE) and postemergence (POST) tank-mix trials were conducted in a PCN-infested LT field to determine which herbicides can be used to 1) control weeds in LT, especially those which can host PCN, e.g. hairy nightshade (*Solanum physalifolium*), and 2) kill LT at the end of the growing season plus control it in crop and non-crop situations so that it does not become a weed. In the PRE trials, 93 to 100% control was provided by most treatments of linuron, metribuzin, or flumioxazin applied alone or in two-way mixtures with each other or fomesafen or pendimethalin. Otherwise, stand reduction by PRE-applied desmedipham-phenmedipham (Betamix), rimsulfuron, or ethalfluralin alone was less than 10%; was 15% by s-metolachlor; and 20 to 22% with EPTC or dimethenamid-p. EPTC or dimethenamid-p effect on stand was “safened” when combined with ethalfluralin or napropamide. Betamix also safened EPTC. In the POST trial, only aminopyralid provided 100% kill, while fluroxypyr, glyphosate, imazamox, or imazapic controlled LT 30 to

50%. LT tolerated several POST treatments such as linuron, rimsulfuron, dicamba, MCPA amine, or bromoxynil. Even though metribuzin killed the LT when applied PRE, it was well-tolerated when applied POST. Treatments included in the end-of-season kill trial were diquat, fluroxypyr, glufosinate-ammonium, bromoxynil, carfentrazone, pyraflufen, and glyphosate alone and in various two-way tank mixtures. Both leaf and stem desiccation were rated to determine kill. By 16 days after application, the relatively fastest leaf desiccation was 86 to 90% by glufosinate-ammonium tank-mixed with carfentrazone or pyraflufen, followed by the 80% leaf desiccation by glyphosate + fluroxypyr. Those treatments were providing 42 to 60% stem desiccation. Glyphosate, pyraflufen, or diquat alone resulted in 50 to 62% leaf desiccation and 42 to 48% stem desiccation at that time. All other treatments caused 11 to 33% leaf and stem desiccation. Glyphosate + bromoxynil was providing less overall desiccation than glyphosate alone.

Evaluation of Thermal, Mechanical, and Chemical Weed Control in Organic Northern Highbush Blueberries (*Vaccinium corymbosum*) in Oregon. Erik N. Augerson*, Marcelo L. Moretti; Oregon State University, Corvallis, OR (131)

Many organic blueberry growers apply synthetic mulches in the planting row and use hand-weeding to manage weeds. As hand-weeding costs increase, cost-effective alternatives are required. The object of this study was to evaluate the efficacy of saturated-steam (SW-900), brush-weeding (ID-brush weeder), ammonium nonanoate (AXXE®), and capric+ caprylic acid (Suppress®) to an untreated control. The experiment design was a five by five factorial arranged in a complete block with four replicates. Treatments were followed by a second application 28 days later, that resulted in all possible combinations (25 treatments). Sharp-point fluvellin (*Kikxia elatine*) and prostrate knotweed (*Polygonum aviculare*) were the most abundant weeds in the study. No significant interactions among sequential treatments were observed. At 28 DAT, total weed biomass was significantly reduced by saturated steam, brush weed, and ammonium nonanoate. A significant interaction among treatments was observed at the final evaluation. All treatments that included saturated-steam resulted in excellent total weed control (83-93%) regardless of the initial treatment. Performance of brush-weeder (58-89%), ammonium nonanoate (48-81%), and capric + caprylic acid (45-75%) were superior after a successful initial treatment, indicating that these treatments perform better against smaller weeds. Cost analyses indicate that saturated-steam and the brush-weeder were the most cost-effective tools at the cost of $32 and $42 per application per treated acre, respectively. Ammonium nonanoate and capric + caprylic acid, cost $270 and $187 per treated acre, respectively. Saturated steam and brush weeder are cost-effective weed control alternatives. These are early data from a study that continues until 2020.

Weed Control Strategies for Interseeding of Cover Crops in Non-Transgenic Sweet Corn. Ed Peachey*, Andrew Donaldson; Oregon State University, Corvallis, OR (132)

Cover crop establishment for producers of non-transgenic sweet corn in western Oregon is challenging after harvest, particularly for late planted corn, or if fall rains begin early. Drilling cover crop seed between corn rows mid-season is one option, but without the option of glyphosate to control weeds postemergence, weed control may suffer. Three 4-HPPD herbicides are currently available for use in sweet corn for broad-spectrum postemergence weed control that have short soil residual and may be compatible with interseeding of cover crops. The objective of this research was to evaluate cover crop establishment and productivity, weed control, and sweet corn yield when applying tembotrione or topramezone at the same time that cover crops were drilled or broadcast seeded at V4, V6, or V8 in sweet corn. Applying tembotrione or tembotrione when interseeding cover crops by both drilling and broadcasting at V6 optimized weed control and cover crop growth. Interseeding at V4 reduced corn yield because of competition from the cover crop. Spring oat, triticale, and crimson clover growth were unaffected by tembotrione or topramezone, whether the cover crops were drilled or broadcast on the soill surface. Applying tembotrione, topramezone, or tolpyralate when cover crops are interseeded into sweet corn may be a viable strategy to improve cover crop establishment without sacrificing weed control.

Mulches for Weed Control on Non-Irrigated Hop (*Humulus lupulus*) in North Dakota. Nick Theisen*, Collin Auwarter, John Stenger, Andrej Svyantek, Harlene M. Hatterman-Valenti; North Dakota State University, Fargo, ND (133)

Hop (*Humulus lupulus* L.) a herbaceous perennial, is a high value crop critical in beer production. Interest to grow hop as niche local market crop have become increasingly popular in areas not known for the crop's culture, such as North Dakota. Little research on hop growth and production techniques in the United States have been conducted outside the Pacific Northwest. Consequently, non-traditional growing areas generally have few chemical options registered for use in hop production. Furthermore, increases in herbicide resistance species, food product regulation constrains, and diversification of production systems have prompted interest in herbicide alternative weed control methods. This research aims to evaluate the effect of mulching use as an alternative weed control method on mature hop production systems. Field experiments were conducted in 2017 & 2018 at the NDSU Horticulture Research site near Absaraka, ND to evaluate the growth and yield characteristics of three commercial hop cultivars in response to mulch weed control options. Hop cultivars 'Cascade', 'Santiam', and 'Mt. Hood' were grown under landscape fabric, straw much, woodchip mulch, and a non-mulched control in a standard hop trellis system. Plant biomass, plant height, cone dimensions, and yield were taken prior and after mechanical harvest. 'Cascade' had significantly higher yield, cone size, and biomass compared to cultivars 'Santiam' and 'Mt. Hood'. However, no significant differences were found between mulch treatment selections. Results suggest potential for a variety of mulching options to be used by growers and hop as a specialty crop in North Dakota.

Testing Bicyclopyrone for Crop Tolerance and Weed Efficacy in Cole Crops. Steven S. Seefeldt*, Tim W. Miller; Washington State University, Mount Vernon, WA (134)

Cole crops such as broccoli, cabbage, Brussels sprouts and cauliflower are widely grown in western Washington. Because the few herbicides registered for these crops are not as efficacious or long lasting as growers need, they often must rely on hand weeding, which negatively impacts economic sustainability. Bicyclopyrone was tested for crop tolerance and weed efficacy in broccoli, Brussels's sprouts, cabbage, and cauliflower both pre and post emergence to determine if this herbicide will be useful to growers. The trial was conducted at the WSU-Mount Vernon Northwestern Research and Extension Center. Treatments included a control, broadcast 37.5 or 50 g/ha bicyclopyrone, with or without 281 g/ha oxyfluorfen (Goaltender 4 SC), or with or without 1.1 kg/ha napromide (Devrinol 2 XT) pre transplant and a two week post-transplant shielded sprayer application of 50 g/ha bicyclopyrone with or without oxyfluorfen and with a nonionic surfactant to row middles. Post-transplant applications resulted in earlier and greater yields of broccoli compared to both rates of bicyclopyrone with or without napromide and the control despite both post-transplant treatments initially causing over 20% injury to the crops. The control and the bicyclopyrone alone treatments resulted in reduced biomass production in cabbage, Brussels sprouts, and cauliflower. Throughout the course of the study, post-transplant bicyclopyrone with or without oxyfluorfen and the two pre transplant rates of bicyclopyrone with oxyfluorfen were better at reducing weed cover than other treatments. These 4 treatments reduced the covers of pale smartweed, lambsquarters, and shepherd's-purse (the most abundant weed species) more than twice as much as other treatments. Directed post-transplant applications of bicyclopyrone with or without oxyfluorfen may provide better weed control and improve yields of cole crops in western Washington.

Optimizing Performance of Pronamide Applied by Sprinkler Chemigation in Lettuce. Jesse M. Richardson*[1], Barry Tickes[2]; [1]Corteva AgriScience, Mesa, AZ, [2]University of Arizona, Parker, AZ (135)

Application of pronamide (Kerb® SC herbicide) through overhead sprinklers has become the dominant weed control tactic in lettuce (*Lactuca sativa*) in the low desert production areas of Arizona and Southern California. It is also becoming increasingly commonplace in coastal production areas. To enjoy the full benefits of this technology, it is important to avoid application errors. Chemigating prematurely after initiating germination irrigations results in inadequate distribution of pronamide in the weed seed germination zone, causing inconsistent weed control. Inadequate chemigation or incorporation water volume can result in excess concentration of pronamide in the seed germination zone. Excess chemigation or incorporation water can result in an outcome similar to chemigating prematurely. Chemigating during excessive wind or through sprinklers that are in poor condition can lead to uneven distribution of the herbicide, resulting in poor weed control. Following label directions relating to application parameters will result in consistent, effective weed control.

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Use of Pyroxasulfone in Potato Weed Management. Andy Robinson*; North Dakota State University / University of Minnesota, Fargo, ND (136)

Paper withdrawn

Weed Management Options for Seeded Onion in North Dakota. Harlene M. Hatterman-Valenti*, Collin Auwarter; North Dakota State University, Fargo, ND (137)

Onion is a crop that requires good weed control throughout the season because it is slow to emerge and never canopies the row middles. Few herbicides are registered for use in onion and with the need for weed control over a period of at least 120 days, multiple herbicides are often applied more than once. Bicyclopyrone belongs to the hydroxyphenlpyruvate dioxygenase inhibitor class of herbicides. Currently it is registered on field corn, seed corn, silage corn, yellow popcorn, and sweet corn. Some previous research has shown onion safety and good season-long weed control with bicyclopyrone. The current research evaluated bicyclopyrone alone and as a mixture when applied preemergence (PRE) and early postemergence (EPOST) to four onion cultivars: Calibra, Delgado, Hamilton, and Sedona. The PRE application occurred 10 days after planting (DAP). The (EPOST) application occurred 24 DAP when onion seedlings were flag leaf to one-true-leaf stage, while the later postemergence (LPOST) application occurred 38 DAP when onion plants were at the two-true-leaf stage. All herbicide treatments provided redroot pigweed and common lambsquarters control when evaluated 50 days after the first application. The only exception was for common lambsquarters control when oxyfluorfen was applied EPOST followed by bromoxynil as the LPOST application. All treatments that contained bicyclopyrone reduced onion stand counts 30 DAP compared to the hand-weeded control. Greatest total onion yields occurred with the hand-weeded plots and plots treated PRE with pendimethalin (Satellite HydroCap) followed by EPOST oxyfluorfen+bromoynil, except with cultivars Hamilton and Sedona. Results indicate that bicyclopyrone applied either PRE or EPOST is not safe to onion seeded into a sandy loam soil in ND.

Weed Management Options in Cold Hardy Grapes. John Stenger, Harlene M. Hatterman-Valenti*; North Dakota State University, Fargo, ND (138)

To enable production under the challenging environmental conditions of North Dakota, specialized cropping practices may be required. North Dakota offers challenges both due to harsh winter conditions as well as low precipitation. These areas may be impacted by weed control options, especially those which influence the near-vine microclimate. Alternative weed control methods were tested in an experimental vineyard near Absaraka, ND for their ability to control annual weed species as well as for their effects on vine growth and production. The experiment was planted in 2012 and arranged in a randomized complete block design with a full factorial including four cold-climate white wine cultivars (‘Alpenglow’, ‘Brianna’, ‘Frontenac Gris’, and ‘La Crescent’) and six within-row weed control methods (woven landscape fabric, herbicide (glufosinate-ammonium, 32 fl. oz/A, with flumioxazin, 6 oz/A), black polyethylene film, straw mulch, tillage, and turfgrass) with four replications. Yield was impacted by weed control measure in Alpenglow and Brianna. In Alpenglow, plants treated with either black film or landscape fabric had higher yields than those treated with herbicide. Brianna vines treated with turfgrass had statistically lower yields compared to all other methods. These differences in yield were due to differences in average cluster size and relative number of clusters produced. Custer weight was significantly lower in turfgrass treated Brianna vines relative to all other methods of weed control. Frontenac Gris vines receiving either landscape fabric or turfgrass had larger clusters when compared to those treated with either straw or herbicide. Alpenglow vines had differences in cluster weight which mimicked trends in overall yield. Fruit pH and titratable acidity did not statistically differ across treatments. Brix was only affected by weed control treatment in Brianna vines, however, such differences were year dependent indicating an increased sensitivity to environmental variations in Brianna relative to the other regional cultivars. Overall, both landscape fabric and polyethelene film were effective alternatives weed control methods in comparison with traditional herbicide use for the six-year period.

The Effect of 2,4-D in Hazelnut Quality and Maturity. Larissa Larocca de Souza*, Marcelo L. Moretti; Oregon State University, Corvallis, OR (139)

Hazelnut suckers are controlled to maintain a single trunk, facilitating mechanical harvest. 2,4-D is commonly used for sucker control in hazelnut, but growers suspect 2,4-D delays natural drop of hazelnut. Nut drop delay can affect harvest because of the onset of the rainy season and muddy conditions reduce harvest efficiency and nut quality. A field experiment was conducted to assess the impact of 2,4-D on nut drop. Treatments included glufosinate (1.1 kg ai ha-1), 2,4-D at 1 (field rate) up to 4 kg ae ha-1, 2,4-D simulated drift at 0.01 and 0.1 kg ae ha-1, and an untreated control. Hazelnut drop was monitored twice a week by counting nut drop and whole plot harvest until the end of nut drop. Non-linear regression was used to estimate the time for 50% nut drop. Simulated 2,4-D drift delayed nut drop by 5 and 15 days in the 0.01 and 0.1 kg ae ha-1 treatments, respectively. Time to 50% nut drop among all other treatments was similar to the untreated control plots (260 days). When comparing the plot harvest, nut drop was delayed by three days only in the simulated 2,4-D-drift at 0.1 kg ae ha-1. Estimated 50% drop (262 days) did not differ among all other treatments. Trees in the simulated drift treatments retain some hazelnuts six months after drift application. These data indicated that 2,4-D can delay nut drop when drifted into the crop, highlighting the importance of drift control measures.

Defining Amicarbazone Rates and Timing of Application for *Poa annua* Control on Golf Course Fairways. Kai Umeda*; University of Arizona, Phoenix, AZ (140)

Annual bluegrass (*Poa annua*) is a problem weed in winter overseeded and non-overseeded turfgrasses in the southwest desert region of the U.S. Generally, it begins to appear in October and through the winter months when cooler temperatures are favorable for its emergence and establishment. There are few postemergence herbicides that effectively and safely control the weed in overseeded perennial ryegrass in summer bermudagrass. Amicarbazone applications are being refined as new suspension concentrate (SC) formulations are developed and being marketed. Since 2015, the spring timing of application during February to early March appeared to be more efficacious and consistent than earlier winter applications. Sequential applications at 2 weeks apart provided acceptable *P. annua*control. Rates of 0.125 to 0.140 lb a.i./A and higher performed comparably and consistently to control *P. annua* at 89% or better while lower rates were not adequate and only marginally controlled *P. annua*. Higher rates of amicarbazone 2SC caused slight chlorosis of the treated perennial ryegrass. Most treatments caused severe injury and thinning of the ryegrass where overlapping sprays were started and ended at the front and back of treated experimental plots.

PROJECT 3: WEEDS OF AGRONOMIC CROPS

Tolerance of Spring Planted Tall Fescue Grown for Seed to Fall Applications of Two Pyroxasulfone Herbicide Products. Dan W. Curtis*, Kyle C. Roerig, Andrew G. Hulting, Carol Mallory-Smith; Oregon State University, Corvallis, OR (081)

Spring planting of tall fescue grown for seed production has become the predominate method for crop establishment. Spring planting takes advantage of rising soil temperatures which reduces annual bluegrass germination in the newly seeded tall fescue crop. The crop forms a crown during the summer and goes dormant as rainfall diminishes in early July. With the onset of rainfall in October and falling soil temperatures, weed management begins. Prior to November 2018, the only fall preemergence herbicide treatment labelled for use in plantings with no prior seed harvest was pendimethalin. Pendimethalin has been shown to be ineffective to prevent germination of Poa species and annual ryegrass in tall fescue. Fierce (pyroxasulfone/flumioxazin) received a label in November 2018 which includes fall applications to spring planted grass seed crops that have at least 8 tillers. The objective of this study was to evaluate crop tolerance of spring planted tall fescue to two pyroxasulfone herbicide products, Zidua (pyroxasulfone) and Fierce, at 1X and 2X rates (pyroxasulfone at 0.098 and 0.195 lb ai/A and pyroxasulfone/flumioxazin at 0.143 and 0.285 lb ai/A) applied in the fall. Pendimethalin treatments at 1X and 2X rates (3.3 lb ai/A and 6.6 lb ai/A) were included for comparison. Applications were made at two fall timings, October 16 and November 20, 2017. The tall fescue growth stage was 2 to 5 tillers at the first application timing. Visual assessments of crop injury and weed control were made at the end of October and mid-November prior to the second application. Assessments were made again mid-December, the end of January and the end of February. The plots were swathed July 5, 2018 and seed was harvested on July 19, 2018. Mid-December evaluations indicated 5 and 10% injury to the tall fescue with the 1X and 2X rates of pyroxasulfone from the October timing. December injury ratings for the pyroxasulfone/flumioxazin were similar to the pyroxasulfone alone with 4 and 14% injury with the lower and higher rates, respectively. February injury observations were 0 and 11% in the early pyroxasulfone treatment and 0 and 4 % with the later pyroxasulfone treatments at the 1X and 2X rates. The pyroxasulfone/flumioxazin resulted in 4 and 11% with the 1X and 2X treatment rates at the early timing and 1 and 5% injury in the 1X and 2X treatments at the later timing in February. Tall fescue in the pendimethalin treatments displayed no injury at either timing. Annual bluegrass at 2 leaf to 1 tiller growth stage was present at the at the time of the October application. Visual control ratings showed both pyroxasulfone products controlling the annual bluegrass 98 to 100 % with the early timing in December. The early pendimethalin treatments were controlled 48 and 85 % of the annual bluegrass in December. February ratings for control of annual bluegrass were 90 and 95% for the early pyroxasulfone, 95 and 98% for the early pyroxasulfone/flumioxazin and 43 and 70% for the early pendimethalin treatment. The late application of the pyroxasulfone controlled 23 and 75% of the annual bluegrass in the 1X and 2X treatments, the late pyroxasulfone/flumioxazin 65 and 80% in the 1X and 2X treatments and the later pendimethalin controlled 5 and 12% in the 1X and 2X treatments. Yield comparison showed no differences between treatments although all herbicide treatment averages were greater than the untreated control. Based on this research pyroxasulfone containing products would provide useful grass weed management in the fall for stands of spring seeded tall fescue.

Impact of Adding Thiencarbazone to Mesosulfuron on Rattail Fescue Efficacy and Overall Weed Management in the Pacific Northwest. Monte D. Anderson*; Bayer CropScience, Sprangle, WA (082)

The addition of thiencarbazone to mesosulfuron has been evaluated over the past six years and will be offered in 2019 as Osprey XTRA. This product will contain a higher level of the safener mefenpyr diethyl. Its initial use will be in the Pacific Northwest and will offer a significant improvement in rattail fescue efficacy over mesosulfuron alone. Rattail fescue efficacy is increased 30- 35% over current postemergence herbicides in winter wheat. Overall grass and broadleaf weed control is increased about 10-15% over mesosulfuron alone. Crop rotational intervals will be similar to mesosulfuron alone or thiencarbazone alone which continue to allow rotational flexibility to the succeeding crop year. Mesosulfuron plus thiencarbazone will have the same wide crop application window of 1 leaf to 2 node as mesosulfuron. Additionally, the use rates and adjuvant requirements are the same as what has been available in the Pacific Northwest since the initial registration of mesosulfuron. Both mesosulfuron and the mesosulfuron plus thiencarbazone combination have exhibited greater grass efficacy when tank mixed with liquid formulations (primarily EC based) of the common broadleaf tank mix partners than without those broadleaf partners, which is a unique distinction among grass weed herbicides. With all of these characteristics in common, a smooth transition is anticipated over the next few years in addition to being the first effective postemergence option for rattail fescue in winter wheat.

Advances in Broadleaf Weed Management in Clover Grown for Seed in Oregon. Andrew G. Hulting*, Kyle C. Roerig, Dan W. Curtis, Carol Mallory-Smith; Oregon State University, Corvallis, OR (083)

Red, white, and crimson clovers grown for seed are important crops in some areas of western Oregon. For grass seed and wheat growers, they represent dicot rotational crops in a cropping system dominated by monocots and they provide good economic returns. To sustain these economic returns, seed quality and purity is important. Broadleaf weed species can negatively impact clover seed quality. Therefore, a number of studies are ongoing in an effort to improve broadleaf weed management options for clover seed growers. Dock spp., primarily curly dock and broadleaf dock, are problematic in red and white clover fields. Dock spp. are competitive perennials with large taproots that thrive in wet areas. The presence of dock spp. can reduce seed yield through competition. In a survey of western Oregon seed cleaners dock spp. were a common contaminant found in seed lots and is very difficult to clean out of clover seed resulting in further clover seed yield loss. Previous research efforts to control dock have focused on the use of 2,4-DB and asulam in established red and white clover. These data indicate excellent crop safety and acceptable dock control with 2,4-DB and excellent dock control and mixed crop safety with asulam. During 2017 we conducted a study to assess control of seedling dock with 2,4-DB and with preemergence and early POST applications of flumetsulam. Results from that study indicated that flumetsulam applied at 0.067 and 0.133 lb ai/a to red clover shortly after planting (preemergence), at the first trifoliate stage (early postemergence), and when clover growth was 3-

5 inches provided 99% or greater control of dock at both rates at the earliest timings. Flumetsulam applied to clover with 3-5 inches of growth exhibited excellent crop safety, but failed to provide adequate control of dock. Injury was observed with both the higher and lower application rates. At the higher rate injury was visually assessed at 75-80% and yield was significantly reduced (at p-value 0.05) compared to the untreated control. At the lower rate injury was also observed, but yield was equivalent to the untreated control (at p-value 0.05). 2,4-DB was applied at two timings and three rates. Dock control among these rates and timings was somewhat variable but tended to be better at higher rates and later timings, with the highest rate providing 74% control at the later timing. Although 100% control is always ideal, 74% control is significantly better than any options currently available. At all rates and timings of 2,4-DB tested crop safety was excellent and yield was not affected. The addition of bromoxynil did not improve dock control. Vetch is a problem in crimson clover grown for seed because it competes for resources, reducing crimson clover yield and vetch contaminates clover seed decreasing its value and increasing losses at the seed cleaner. Controlling vetch in crimson clover grown for seed in the field is especially difficult because both are annual legumes with similar growth habits. Two herbicides with suspected crop safety in crimson clover were evaluated. An untreated control and a grower standard, imazamox + bentazon, were also included. Crimson clover injury was 20-23% eleven weeks after application when 2,4-DB was applied November 1st at the higher two rates. By May 5th injury was no longer visible and the plots yielded equivalent to the untreated and grower standard. Vetch was not controlled by 2,4-DB, but since crop injury and yield were acceptable 2,4-DB could be a useful tool for controlling other important weeds in crimson clover. Flumetsulam was applied November 1st and March 20th at two rates. Neither rate or timing of the flumetsulam injured the crimson clover and yield was equal to or greater than the untreated check or grower standard. The vetch control with both rates and timings was 70-83% and were equivalent (at p-value 0.05). The control observed was primarily the stunting of plants and the suppression of flowering. Since one of the primary objectives of the grower is seed purity and currently registered herbicides provide inadequate control of vetch, flumetsulam would be a valuable tool if it were registered for use in crimson clover.

Economic Implications of Herbicide Resistant Weed Management in Glyphosate-Resistant Sugarbeet. Albert T. Adjesiwor*[1], Nevin C. Lawrence[2], Prashant Jha[3], Todd A. Gaines[4], Eric Westra[4], Andrew Kniss[1]; [1]University of Wyoming, Laramie, WY, [2]University of Nebraska-Lincoln, Scottsbluff, NE, [3]Montana State University, Huntley, MT, [4]Colorado State University, Fort Collins, CO (084)

Glyphosate-resistant (GR) sugarbeet (*Beta vulgaris* L.) have been widely adopted by growers primarily due to the economic benefits. However, the value of this trait is beginning to erode, as weeds continue to evolve resistance to glyphosate. Field studies were conducted in Colorado, Montana, Nebraska, and Wyoming, to evaluate one component of the economic impact of GR kochia (*Kochia scoparia* (L.) Schrad.) and GR Palmer amaranth (*Amaranthus palmeri* S. Wats.) in GR sugarbeet. Five herbicide programs were applied in a randomized complete block design with six replicates at all locations. Treatments included a weed-free control treatment that was sprayed with only glyphosate, and four herbicide treatments where additional herbicides were added to the glyphosate. These four herbicide treatments were chosen based on our expectation that they would provide the best control possible of GR kochia (2 treatments) and GR Palmer amaranth (2 treatments). For each species, one herbicide program was selected that would provide POST control, and a second herbicide program was selected that would rely on the 'layered residual' concept, where residual herbicides are applied multiple times throughout the season. No glyphosate-resistant weeds were present at any of the four field sites, and therefore, all weeds were well-controlled by the herbicide treatments. This allowed us to quantify sugarbeet injury and yield loss based only on the herbicides being applied, and not confounded by weed competition. When harvested at the 10 to 12 true-leaf stage, POST treatments reduced biomass (14 and 23% per root) more than layered residual treatments (3 and 17% per root). Averaged over sites, the POST herbicide treatment targeting Palmer amaranth reduced sucrose yield at harvest by 11%, while the POST herbicide treatment targeting kochia reduced sucrose yield 4%. Additional economic impacts have also been analyzed, but vary with price and cost estimates.

Herbicides for Sainfoin Stand Removal and Methods of Evaluation. David A. Claypool*[1], Andrew Kniss[1], Gustavo M. Sbatella[2]; [1]University of Wyoming, Laramie, WY, [2]University of Wyoming, Powell, WY (085)

Management options for removing a declining stand of sainfoin (*Onobrychis viciifolia*) have not been studied extensively. Sainfoin is known to be relatively tolerant of glyphosate but applications have been shown to reduce stands and cause revenue loss. A study was conducted in 2016 at the Powell Research and Extension Center, Powell, WY, to evaluate herbicides for sainfoin removal and to compare three methods of stand evaluation. Field plots were irrigated, 11 ft x 25 ft in size, and arranged in a randomized complete block design with 4 replicates. Herbicide treatments were Roundup PowerMax (glyphosate) at 3.8 lbs ai/A, 2,4-D amine at 0.5 and 1.0 lbs ai/A, Clarity (dicamba) at 0.25 and 0.5 lbs ai/A, and Stinger (clopyralid) at 0.1 and 0.2 lbs ai/A, plus a nontreated control. Two application timings were tested. Study 1 treatments were applied July 9 after the first cutting and evaluated July 26. Study 2 treatments were applied August 29 after the second cutting and evaluated on September 26. Methods used to evaluate treatment effects were visual injury rating on a 0 (no injury) to 100 (complete plant death) scale, Greenseeker normalized difference vegetation index (NDVI), fractional green canopy cover (FGCC) using the Canopeo mobile device application, and above-ground fresh biomass. ANOVA was conducted and means compared using Fisher's protected LSD at alpha of 0.05. For all methods of stand evaluation, Roundup was significantly different from the other treatments in both studies. Evaluations in Study 1 were conducted 17 days after treatment (DAT). Roundup produced the highest injury rate (88%); the remaining treatments ranged from 53 to 74% injury. NDVI of the nontreated control and Roundup treatment were 0.81 and 0.40, respectively. NDVI of the other treatments ranged from 0.63 to 0.71. FGCC of the nontreated control and Roundup were 88.1% and 21.1%, respectively. Most other treatments were not significantly different from each other and ranged from 52.1 to 72.5%. Biomass of 2,4-D, Clarity, and Stinger treatments were not significantly different, ranging from 1.10 to 1.50 tons/A. Biomass of the nontreated control and Roundup were 4.08 and 0.65 tons /A, respectively. Study 2 evaluations were conducted 28 DAT. Injury from Roundup was 91%; injury from other treatments ranged from 38 to 69%. NDVI of the nontreated control and Roundup were 0.86 and 0.28, respectively, and ranged from 0.56 to 0.71 in the other treatments. FGCC for the nontreated control and Roundup were 94.0 and 4.1%, respectively, and other treatments ranged from 33.7 to 56.9%. Biomass of the nontreated control was 1.43 tons/A. Roundup had the lowest biomass production (0.07 tons/ac) but was not significantly different from 2,4-D, Stinger, and Clarity at 0.5 lbs ai/ac, which ranged from 0.14 to 0.31 tons/A. Biomass production was correlated to injury, NDVI, and FGCC. Pearson r values for Study 1 were -0.896, 0.660, and 0.615, respectively, and -0.775, 0.683, and 0.791, respectively, in Study 2. All were significantly different at $P<0.001$. Treatment cost per acre including adjuvants (ammonium sulfate and nonionic surfactant) at 2019 prices were: Stinger (8 fl oz/ac) $37.76, Roundup (108 fl oz/ac) $26.68, Stinger (4 fl oz/ac) $20.26, Clarity (16 fl oz/ac) $15.26, Clarity (8 fl oz/ac) $9.01, 2,4-D (32 fl oz/ac) $5.76, and 2,4-D (16 fl oz/ac) $4.26.

Antagonism of Volunteer Corn Control by Dicamba and 2,4-D. Joseph E. Mettler*, Kirk A. Howatt; North Dakota State University, Fargo, ND (086)

Herbicides used to control glyphosate resistant volunteer corn in soybean cropping systems might be antagonized by high rates of dicamba or 2,4-D in the new crop technologies. Various rates of acetyl CoA carboxylase inhibiting herbicides were tank mixed with dicamba or 2,4-D to evaluate antagonism of volunteer corn control. Studies were conducted in 2018 near Fargo, North Dakota as a randomized complete block design with four replicates. Dicamba or 2,4-D were applied at 8 and 16 ounces of active ingredient per acre, respectively. Low, medium and high rates of the recommended rates of quizalofop, sethoxydim and clethodim were tank-mixed with dicamba or 2, 4-D. In the dicamba study, quizolofop controlled 98% of volunteer corn on average, across all rates, resulting no antagonism. However, all other treatments of grass herbicides, including 2,4-D mixed with quizalofop, were antagonized by the addition of dicamba or 2,4-D. When antagonism occurred, similar levels of volunteer corn control compared to quizalofop (0.35 oz ai/acre) or sethoxydim (1.2 oz ai/acre) alone was not achieved unless the high recommended rate was applied, 0.9 and 3 oz ai/acre, respectively. A similar level of control to clethodim (0.75 oz ai/acre) alone was obtained by raising the rate of clethodim to 1 oz ai/acre when either dicamba or 2,4-D was included. In conclusion, sethoxydim resulted in poor control overall, and should not be used to control volunteer corn. And the high recommended rates of quizalofop and clethodim should be used when tank-mixed with dicamba or 2,4-D to avoid antagonism.

Soybean Yield, Seed Germination, and Leaf Tissue Analysis as a Result of Simulated Dicamba Drift. Mike H. Ostlie*[1], Joao Paulo Flores[1], Kirk A. Howatt[2], Greg J. Endres[1], Rich Zollinger[3], Devin Wirth[2]; [1]North Dakota State University, Carrington, ND, [2]North Dakota State University, Fargo, ND, [3]Amvac Chemical Company, Spokane, WA (087)

Field trials were conducted in 2017 and 2018 near Carrington and Fargo, ND to evaluate how micro-rates of dicamba and glyphosate impact soybean performance. Dicamba doses were 0.007, 0.07, 0.7 oz ai/a. Aerial imagery was collected to measure crop injury concurrent with ground-based phytotoxicity ratings. Leaf tissues were collected 10 DAT and herbicide residues quantified. Yield, protein, and seed germination data also were collected. Aerial imagery was analyzed to output four indices; NDVI, NDRE, GNDVI, and Excess Green. All imagery had a strong correlation to collected visual injury and yield data. Excess Green had a poorer relationship than the other indices, however, it is also the most practical index to use due to availability of the image capture technology. At each site, there was a relationship between dicamba dose and herbicide residue in the leaf tissues. However, each site had a different pattern of relationship between leaf concentration and plant response, indicating low predictive value across environments. Injury extent varied with year as well with little or no symptoms occurring with lowest dose at some sites while other sites had moderate amounts of leaf cupping. Upper dicamba doses generally had similar responses across sites. Medium and high doses also caused delays in plant maturity. Soybeans treated with a high dose relied on a frost event to facilitate plant dry-down. Yields were only impacted with the highest dose of dicamba. Germination was impacted by some years by the highest dose of dicamba, however due to the delay in a maturity and low yield, it is not likely those plants would be harvested.

Improving Herbicide Effectiveness and Minimizing Impacts with Research, Analysis, Visualization, and Demonstration. Gregory K. Dahl*[1], Ryan J. Edwards[2], Eric Spandl[2], Joshua J. Skelton[3], Annie D. Makepeace[4], Lillian C. Magidow[3]; [1]Winfield United, RIVER FALLS, WI, [2]WinField United, River Falls, WI, [3]Winfield United, River Falls, WI, [4]Winfield United, Arden Hills, MN (088)

Winfield® United, a Land O' Lakes Company and its legacy companies have worked for a long time to improve the effectiveness of herbicide applications and minimize off-target issues. Several herbicides, adjuvant products and application methods have been developed and brought to market. Field testing has been a strong part of the research program to evaluate product performance. Winfield United recently opened an Innovation Center in River Falls, Wisconsin. The Winfield United Innovation Center greatly increased the ability of Winfield United to build and test new herbicide and adjuvant formulations. Spray droplet analysis is conducted in an industry leading wind tunnel and testing facility. Potential spray mixtures are evaluated for the risk of loss due to particle drift. Greenhouse facilities and growth chambers grow plants for testing. Growth chambers help for evaluating the influence of environmental conditions. Winfield United also has a new spray booth. This spray booth can be used to apply spray mixtures with multiple nozzles at field speeds up to 18 miles per hour. Various spray collection methods and different imaging technology can be used to observe droplets behavior and interaction with leaves. Other instruments and methods that determine how droplets behave on different waxy or hairy leaf surfaces. Winfield United is involved in Precision Agricultural Technology, GPS mapping and forecasting tools to improve decision making and weed control results. "SUSTAIN™ is a new program which is used to improve sustainability and reduce the impact of agriculture and its practices on the environment.

Introducing a New NPE Free Non-Ionic Surfactant. Ryan J. Edwards*[1], Gregory K. Dahl[2], Tom A. Hayden[3], Jo A. Gillilan[4], Joe Gednalske[1], Eric Spandl[1]; [1]WinField United, River Falls, WI, [2]Winfield United, River Falls, WI, [3]WinField United, Owensborro, KY, [4]WinField United, Springfield, TN (089)

Introducing Permeate™ (NPE free surfactant-based adjuvant) from Winfield® United. Permeate™ adjuvant is a next generation non-ionic surfactant that will help optimize application coverage. Permeate™ has been shown maximizes pesticide performance by improving droplet spreading through decreased contact angles with minimal expected crop injury. Permeate™ also provides patented UV protection, which protects herbicides, insecticides and fungicides from photo degradation. Permeate™ can be applied whenever a pesticide label allows for the addition of a non-ionic surfactant.

Impact of Sublethal Dicamba and Glyphosate on Three Chipping Potato Cultivars. Matthew J. Brooke*, Harlene M. Hatterman-Valenti, Collin Auwarter; North Dakota State University, Fargo, ND (090)

The increase of weedy species resistant to glyphosate has led to the development and release of dicamba-resistant soybean varieties. However, with the increased utilization of dicamba, herbicide off-target injury has become a significant issue for regional farmers. When investigating the impact of drift rates of these two ubiquitous agronomic herbicides, this research explores their effects on three irrigated chipping potato cultivars (Atlantic, Dakota Pearl, and Lamoka) as measured through visible injury, tuber quality reduction, and yield reduction. Herbicides were sprayed at the tuber initiation stage and consisted of dicamba at 99g ae ha-1, glyphosate at 197g ae ha-1, dicamba + glyphosate at 99g ae ha-1 + 197g ae ha-1, and 20 g ae ha-1 + 40 g ae ha-1, respectively, and an untreated control. Pooled across cultivars, at seven days after treatment (DAT), high dicamba + glyphosate caused the most damage, with 28% based on visible ratings. While low dicamba + glyphosate was not different from the untreated control. Furthermore, at 21 DAT, visible injury increased to 36% for the high dicamba + glyphosate treatment. The high combination of dicamba + glyphosate resulted in a 66% yield reduction compared to the untreated control, which averaged 910 cwt ha-1. Tuber specific gravity was also lower for plants sprayed with dicamba. Results from the two field trials suggest that not only can sublethal rates of dicamba + glyphosate significantly decrease potato yields, it also negatively influences tuber specific gravity in chipping quality

Efficacy of Haulaxifen-methyl Plus Florasulam on *Amaranthus* Species. Joe Yenish*[1], Patti Prasifka[2], Mike J. Moechnig[3]; [1]Corteva AgriSciences, Billings, MT, [2]Corteva AgriScience, West Fargo, ND, [3]Dow AgroSciences, Toronto, SD (091)

Waterhemp (*Amaranthus tuberculatis*) populations are spreading north and west in the Northern Great Plains resulting in increasing concern in wheat growing regions. Only two herbicide modes of action, WSSA groups 4 and 27, provide reliable control of waterhemp in cereal crops due to the prevalence of biotypes resistant to other modes of action. Quelex® herbicide was recently introduced by Corteva Agriscience™, Agriculture Division of DowDuPont, for use in cereal crops to control several broadleaf weed species, including redroot pigweed (*Amaranthus retroflexus*), but waterhemp is currently not listed for control on the Quelex label. Quelex is a water dispersible granule (WDG) containing 10% w/w Arylex® active (halauxifen-methyl) and 10% w/w florasulam with a use rate of 52.5 grams of product/ha (0.75 oz product/acre) [Arylex (halauxifen-methyl 5.25 g ae/ha) + florasulam (5.25 g ai/ha)] that may be applied preseed or post emergence up to flag leaf stage of growth. Arylex active is a novel synthetic auxin (WSSA group 4) active ingredient from the arylpicolinate chemical family and florasulam is an ALS-inhibiting herbicide from the triazolopyrimidine chemical family (WSSA group 2). Field research was conducted during the 2014 to 2018 cropping seasons at multiple locations across the Northern Great Plains to determine the efficacy of Quelex on waterhemp, related Amaranthus species and other broadleaf weeds. Resistance to group 2 herbicides was suspected at all waterhemp sites and some redroot pigweed sites. Control of waterhemp with Quelex + WideMatch® herbicide (premix of fluroxypyr and clopyralid) averaged slightly less than 90%. Redroot pigweed control with Quelex + 2,4-D or Quelex + WideMatch exceeded 90% among group 2 susceptible and suspected-resistant sites, which was equal to or greater than comparative treatments. At group 2 suspected-resistant sites, redroot pigweed control with the commercial standard treatment of WideMatch + thifensulfuron + tribenuron declined by more than 25% relative to the susceptible site. Quelex, alone and in tank mixes, 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 *Amaranthus* species in cereals.

Evaluation of Microrate POST Programs in Dry Edible Bean. Clint W. Beiermann*[1], Rich K. Zollinger[2], Andrew Kniss[3], Prashant Jha[4], Nevin C. Lawrence[1]; [1]University of Nebraska-Lincoln, Scottsbluff, NE, [2]Amvac Chemical Company, Spokane Valley, WA, [3]University of Wyoming, Laramie, WY, [4]Montana State University, Huntley, MT (092)

A study was initiated during the 2017 growing season at four different locations: Scottsbluff NE, Lingle WY, Huntley MT, and Prosper ND, to evaluate a split-POST application program utilizing microrates of multiple herbicides for control of pigweed species in dry bean. The study was arranged as a strip-plot, strip plot factor consisted of no-PRE, or pendimethalin (1070g ai ha^{-1}) + dimethenamid-P (790g ai ha^{-1}) applied PRE. Main plot factor, POST herbicide treatment, consisted of all labeled combinations of imazamox, bentazon, and fomesafen applied in one and two pass programs at standard rates, and microrate treatments consisting of imazamox (9g ai ha^{-1}) + bentazon (314g ai ha^{-1}) + fomesafen (70g ai ha^{-1}) applied in one, two, and three sequential applications. Scottsbluff was the only location where ALS-resistant Palmer amaranth was present, redroot pigweed was present at all other locations. In Scottsbluff, the use of a PRE herbicide reduced Palmer amaranth density and biomass, and preserved greater yield. All POST treatments reduced Palmer amaranth density compared to non-treated plots and imazamox + bentazon applied at standard rates. All POST treatments reduced Palmer amaranth biomass compared to non-treated plots. All POST treatments yielded higher than the non-treated and the one pass micro rate treatment. At Huntley, Lingle, and Prosper all POST treatments provided effective control of redroot pigweed. At Huntley and Lingle all POST treatments yielded higher than non-treated. Across locations, the two and three pass microrate system did not enhance weed control compared to a one-pass treatment containing fomesafen at labeled rates.

Paraquat Plus S-Metolachlor: A New Option for Burndown and Residual Control. Stephen M. Schraer*[1], Ryan D. Lins[2], Dane Bowers[3], Monika Saini[4]; [1]Syngenta, Meridian, ID, [2]Syngenta, Byron, MN, [3]Syngenta, Greensboro, NC, [4]Syngenta Crop Protection, Greensboro, NC (105)

Gramoxone Magnum herbicide is a new product for burndown and residual control of grass and broadleaf weeds in corn, legume vegetables, sorghum, soybeans, and sunflower. Gramoxone Magnum is a combination of paraquat (Group 22) and s-metolachlor (Group 15). Upon EPA approval, it will provide two alternative sites of action to glyphosate (Group 9) and has tank mix flexibility for multiple cropping systems.

Weed Emergence Timing in California Rice. Katie E. Driver*, Kassim Al-Khatib; University of California - Davis, Davis, CA (106)

Herbicide application timing is vital to the efficacy of herbicides. The spectrum of weed emergence in a single field makes it difficult to target all weeds present. Many weed species escape application and are thought to be resistant when the failure in control was a mis-timed application. To get a better understanding of emergence times of common problematic weed species in California rice fields, a field study was conducted at three different sites throughout the Sacramento Valley with planting dates ranging from April 26 to June 1. The weed species smallflower umbrella sedge (SF), barnyardgrass (BG), and bearded sprangletop (BS) were planted. One hundred seed of each species was planted in a row and marked. Emergence counts were taken daily. The data was then fit to a predictive thermal time model to estimate weed emergence. The model used calculated the base temperature for emergence and the number of growing degree days (GDD) needed for emergence. SF had a base temperature of 14 C and a lag phase of 9 GDD. BG had a base temperature of 17 C and a lag phase of 13 GDD. BS had a base temperature of 13 C and a lag of 64 GDD. SF emerged first in each field at approximately 5 days after flooding, followed by BG which emerged approximately 5-10 days after flooding, and BS which emerged 15 – 35 days after flooding. The differences in emergence indicate more than one herbicide application time is needed to control the spectrum of weeds present.

Topramezone Plus Atrazine - An Applied Review. Rich Zollinger*[1], Rich Porter[2], Peter Porpiglia[3]; [1]Amvac Chemical Company, Spokane, WA, [2]Amvac Chemical Company, Des Moines, IA, [3]Amvac Chemical Company, Newport Beach, CA (107)

Studies were conducted to identify, develop, and register a premix formulation of topramezone plus atrazine. In 2015 field trials, an optimum ratio of near 1:15 (active ingredient) was identified for topramezone free acid to atrazine, respectively. A premixture of both actives was developed for EPA registration at 8.0 to 10.7 fl oz/A, giving 18.4 g/ha to 24.5 g/ha plus 280 g/ha to 374 g/ha of topramezone and atrazine, respectively. In 2016, this formulation was evaluated in trials conducted at 16 locations with a total of 53 evaluations made on 23 grass and broadleaf weed species. In 2017, weed control efficacy trials were conducted by 28 academic researchers on a total of 45 grass and broadleaf weed species. Weed control averaged across all weed species from a preemergence application of acetochlor plus atrazine followed by a postemergence application of topramezone plus atrazine at 8.0 fl oz/A plus recommended adjuvants was greater than 95%. Addition of glyphosate, glufosinate, or dicamba increased weed control to a range of 96 to 97% weed control. Weed control averaged across all weed species from a single early postemergence application of the mixture of topramezone plus atrazine applied with acetochlor was greater than 95%. In 2018, weed control efficacy trials were conducted by 23 researchers on a total of 43 grass and broadleaf weed species. Weed control averaged across all weed species from a preemergence application of acetochlor plus atrazine followed by a postemergence application of topramezone plus atrazine at 10.7 fl oz/A plus recommended adjuvants was greater than 97%. Addition of glyphosate or glufosinate increased weed control to 98% weed control. Weed control averaged across all weed species from a single postemergence application of the mixture of topramezone plus atrazine applied with acetochlor was greater than 95%. The addition of glyphosate gave 95% weed control. Topramezone and atrazine are highly lipophilic (log Koc = 1.52 and 2.68, respectively) and oil concentrate adjuvants (i.e. MSO) enhance herbicidal activity. Atrazine labels prohibit rotation to most crops the year after application except corn, sorghum, and soybean. The topramezone plus atrazine label allows rotation to several major and minor crops the year after application.

Comparing Biological Characteristics and Control Methods of Kochia and Palmer Amaranth. Andrew D. Effertz*, Phil Westra, Todd A. Gaines; Colorado State University, Fort Collins, CO (108)

Though many research articles have been published describing the characteristics of kochia (*Bassia scoparia)* and palmer amaranth (*Amaranthus palmeri*), these two weeds continue to be among some of the most difficult weeds to control in the United States. This multi-faceted study is exploring the anatomical, physiological, and biological aspects of kochia and palmer amaranth to uncover new information to be added to prior research explaining the competitive advantages and survival abilities these two weeds display. Current research is also looking at the EPSPS amplified contig arrangements that confer differing levels of glyphosate resistance in these two weeds. This study also provides updates on new research on glyphosate and dicamba resistance in kochia found in Colorado, an update on the herbicide resistance screening that's been conducted by Colorado State University across eastern Colorado since 2011, and data from field trials in Eastern Colorado showing herbicide effectiveness on palmer amaranth, which is becoming an increasing problem in Colorado.

Triple-Resistant Kochia in Western Canada: Management Tools and New Research. Charles M. Geddes*[1], Linda M. Hall[2], Hugh J. Beckie[3]; [1]Agriculture and Agri-Food Canada, Lethbridge, AB, [2]University of Alberta, Edmonton, AB, [3]University of Western Australia, Perth, Australia (109)

Kochia [*Kochia scoparia* (L.) Schrad.] thrived in many areas of the Canadian Prairie landscape in 2018, following the "perfect storm" of dry conditions in 2017 followed by variable weather in 2018. Kochia is among the most problematic weeds in southern Alberta, Saskatchewan, and Manitoba Canada, due to abiotic stress tolerance, phenotypic plasticity, prolific seed production, and multiple herbicide-resistance. In Canada, kochia populations resistant to acetolactate synthase (ALS)-inhibitors were discovered in 1988. Over the course of two decades, ALS-inhibitor resistance in kochia spread to the point that all kochia populations in western Canada are considered resistant to these herbicides. More recently in 2011, glyphosate-resistant kochia biotypes were discovered in chemical-fallow fields in southern Alberta. After five years, the incidence of glyphosate-resistance in kochia in southern Alberta grew from 5% of kochia populations in 2012 to 50% in 2017. Populations from the more recent survey were found in several crops, including: wheat, barley, canola, flax, mustard, lentil, field pea, and corn; as well as more-ruderal areas. In addition, dicamba-resistance was found in 18% of kochia populations, while 10% of populations were resistant to all three herbicides (ALS-inhibitors, glyphosate and dicamba). The status of fluroxypyr-resistant kochia in Canada remains uncertain. Chemical options for management of herbicide-resistant kochia are diminishing quickly, and it is becoming clear that we will not successfully spray our way out of this problem. This presentation will cover the status of herbicide-resistant kochia in Canada, and highlight new research investments into an integrated weed management approach.

Genetic Basis of Multiple Herbicide Resistance in Palmer Amaranth (*Amaranthus palmeri* L.). Chandrima Shyam*[1], Sridevi Nakka[1], Karthik Putta[1], Ivan Cuvaca[1], Randall Currie[2], Mithila Jugulam[1]; [1]Kansas State University, Manhattan, KS, [2]Kansas State University, Garden City, KS (110)

Palmer amaranth (*Amaranthus palmeri*), is one of the most difficult weeds to control in the US, which has developed resistance to seven herbicide modes of action. A Palmer amaranth population from Kansas was recently found to have evolved resistance to three commonly used herbicides in Kansas, i.e., ALS-, PS-II, and HPPD-inhibitors. The objective of this research was to investigate the inheritance of multiple herbicide resistance in Palmer amaranth to understand the number of genes controlling these resistances. F_1 progenies were produced by crossing separately plants that were previously assessed to be resistant to ALS-, PS-II, and HPPD-inhibitors with known susceptibles (to all three herbicides). These F_1 progenies, along with parental plants were used in ALS-(chlorsulfuron), PS II-(atrazine) and HPPD-(mesotrione)-inhibitor dose-response experiments to determine the degree of dominance of the genes conferring resistance. Additionally, some of the survivors of F_1 dose-response study were used to generate F_2 progenies, which were further evaluated for their response to the above three herbicides. The segregation of resistance and susceptible phenotypes were assessed in these F_2 progenies. Degree of dominance from F_1dose-response experiments and chi-square analyses of F_2 segregation data indicated that the Palmer amaranth resistance to chlorsulfuron is controlled by a single dominant gene, while atrazine resistance is governed by an incompletely dominant gene. Resistance to mesotrione was found to be polygenic in nature in this population. Studies suggest that though single gene resistance can spread rapidly both via pollen and seed parent, multiple gene traits are slower to evolve, and can confer resistance to unknown mode of action of herbicides. Regardless, management strategies such as crop rotation and application of herbicides with multiple mode of actions can minimize the spread of resistance.

Site-Specific Weed Management in Corn: From UAV to Application. Joao Paulo Flores, Mike H. Ostlie*; North Dakota State University, Carrington, ND (111)

A 40 acre field was planted to corn in 2018 to evaluate the feasibility of site-specific weed management. The field received a PRE application of Verdict. A 10 acre parcel was divided into square cells the width of an on-site sprayer (30 ft). Aerial images were collected with a high resolution RGB camera at the corn V4 growth stage. The Excess Green index was applied to the image to identify growing plants. Corn rows were removed from the images and all remaining green material was categorized as a weed. Cells were binomially characterized for weed presence. Cells with weeds were designated for spraying with an effective post-emergent product. Weed species were identified and counted in subplots within cells on the day of spraying. Species identification and counts were taken once again 2 and 4 weeks after application. After corn harvest a second set of images were collected and analyzed, along with ground-truthing. There were no differences in weed presence between sprayed and non-sprayed cells. Overall area sprayed was 84% of the total. Hypothetical testing was done with smaller cells sizes which would have reduced the sprayed area to 30% of the total by using a one meter cell. The product and water savings possible, even with a 30 ft cell, warrant further investigation into this strategy.

Deciphering the Molecular Basis of Mesotrione Tolerance in Grain Sorghum. Balaji Aravindhan Pandian*, Vara Prasad P.V., Sanzhen Liu, Tesfaye Tesso, Mithila Jugulam; Kansas State University, Manhattan, KS (112)

Sorghum is the fifth most important cereal crop grown worldwide which can produce high yields under limited water and other inputs. Post-emergent grass weed control continues to be a great challenge in grain sorghum production, primarily due to lack of herbicide options unlike in corn. Mesotrione is a broad-spectrum herbicide registered for use in corn, but not as a POST in sorghum due to crop injury. We identified two sorghum genotypes, G-1, and G-10 with elevated tolerance to mesotrione (POST) but the genetic basis of mesotrione tolerance in these genotypes is unknown. The objective of this study was to map the gene(s) responsible for mesotrione tolerance. Reciprocal crosses using mesotrione-tolerant (G-1 and G-10) and -sensitive (S-1) genotypes of sorghum were performed and the F_1 seed were generated. The F_1 progenies were evaluated in a mesotrione dose-response (0 to 8X of mesotrione; where X is 105 g ai ha^{-1}, which is the field used dose) assay. Further, the F_2 seed were generated by self-pollinating the F_1 progenies. The F_2 progenies were treated with 630 ai ha^{-1} (6X of field dose) to examine the segregation of mesotrione tolerance and sensitivity. Plants exhibiting tolerance or sensitivity to mesotrione among F_2progenies were pooled separately into two groups. RNA was extracted from the pooled samples and sequenced using Illumina NextSeq and bulk segregation (BSR-seq) analyses were performed. The results of the dose-response assay indicated that the F_1 progenies exhibited the same level of tolerance as that of tolerant parents. The F_2 progenies segregated into 3:1 (tolerance: susceptibility) ratio suggesting that mesotrione tolerance is controlled by a single dominant gene. Analyses of the BSR-seq data indicate that the putative gene responsible for mesotrione tolerance is located in chromosome 1 between 18.4- 23.9 Mb in sorghum. Experiments are in progress to identify and validate candidate gene conferring mesotrione tolerance in sorghum. The outcome of this research will be valuable for marker-assisted breeding program to develop mesotrione-tolerant sorghum hybrids, thereby improve postemergence grass weed control.

Characterization and Management of Multiple Herbicide-Resistant Kochia in Western Kansas. Vipan Kumar*[1], Rui Liu[1], Randall Currie[2], Prashant Jha[3], Taylor Lambert[1]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Garden City, KS, [3]Montana State University, Huntley, MT (113)

Multiple herbicide-resistant (MHR) kochia has become a serious concern in the semi-arid no-till dryland production systems across the U.S. Great Plains, including western Kansas. More recently, the putative MHR kochia accessions were identified from two fallow fields near Hays, KS, and two corn fields near Garden City, KS. The main objectives of this research were to (1) characterize the response of those putative MHR kochia accessions to commonly used herbicides (dicamba, fluroxypyr, glyphosate, and atrazine), and (2) determine the effectiveness of alternative POST herbicides for controlling these MHR kochia accessions. To fulfill these objectives, separate greenhouse experiments were conducted at Kansas State University Agricultural Research Center near Hays, KS. Whole-plant dose-response studies indicated that the selected MHR accessions from Garden City had 3.1- to 9.4-fold resistance to dicamba and 3.0- to 8.6-fold resistance to fluroxypyr, respectively. Similarly, dose-response studies on Hays accessions showed 5- to 8-fold resistance to dicamba. Additionally, one of the MHR accessions from Garden City had 230-fold resistance to POST applied atrazine. The MHR kochia accessions from Garden City also had 3 to 13 EPSPS (5-enolpyruvyl-shikimate-3-phosphate) gene copies, further indicating multiple resistance to glyphosate. In a separate greenhouse study, POST applied bromoxynil + pyrasulfotole, bromoxynil + bicyclopyrone, saflufenacil alone or with 2,4-D, paraquat alone or with atrazine, metribuzin, 2,4-D provided effective control (95 to 100%) of two MHR accessions from Garden City, KS. These results suggest that the putative MHR kochia accessions from western Kansas had developed moderate to high levels of cross-resistance to dicamba and fluroxypyr; low to high levels of resistance to glyphosate; and very high levels of resistance to atrazine (multiple resistance to three herbicide site(s) of action). This is the first report of kochia accessions with cross-resistance to dicamba and fluroxypyr in western Kansas. Growers should adopt diversified kochia control programs, including effective alternative POST herbicide options (tested in this study), use of cover crops, occasional tillage, and diversified crop rotations to prevent further evolution and spread of MHR kochia on their production fields.

Response of Kansas Feral Rye Populations to Imazamox and Quizalofop-p-ethyl. Rui Liu*[1], Vipan Kumar[2], Taylor Lambert[2], Misha R. Manuchehri[3]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Hays, KS, [3]Oklahoma State University, Stillwater, OK (119)

Feral rye (*Secale cereal* L.) is a troublesome winter annual grass weed species in winter wheat across the western United States, including Kansas. Growers mainly rely on herbicide-resistant (HR) wheat technologies for managing feral rye in winter wheat. The Clearfield™ wheat production system was introduced in 2002 that allowed growers to use POST applications of imazamox (ALS inhibitor) herbicide for controlling winter annual grass weed species, including feral rye. Recently, the CoAXium™ winter wheat production system has been introduced that contains the AXigen™ trait which confers resistance to quizalofop-p-ethyl herbicide (ACCase inhibitor) and can also be utilized for managing feral rye. However, there appears to be a lack of information on the response of Kansas feral rye populations to imazamox and quizalofop-p-ethyl herbicides. Therefore, the main objective of this research was to determine the response of Kansas feral rye populations to imazamox and quizalofop-p-ethyl through dose-response assays. Nine feral rye populations collected from winter wheat fields in central Kansas were investigated. Greenhouse experiments were conducted at Kansas State University Agricultural Research Center near Hays, KS. Experiments were separately conducted in a randomized complete block design, with 12 replications. Doses for imazamox and quizalofop-p-ethyl herbicides were 0, 0.25, 0.5, 1, 2, and 4X of the field-used rates (imazamox 53 g ha^{-1}; quizalofop 62 g ha^{-1}). Methylated seed oil (MSO) at 0.5% v/v and nonionic surfactant (NIS) at 0.25% v/v were included with imazamox and quizalofop-p-ethyl doses, respectively. Data on percent injury and shoot dry weights were collected 21 days after treatment (DAT). All data were analyzed using a 4-parameter log-logistic regression model in R software. Results showed that the lethal dose (GR_{50} values) of imazamox causing 50% shoot dry weight reduction of nine feral rye populations ranged from 3.6 to 24 g ha^{-1}, indicating an 8-fold differences between the most sensitive and the least sensitive population. In contrast, quizalofop-p-ethyl was highly effective even at a low dose. The lethal dose (GR_{50} value) of quizalofop-p-ethyl causing 50% shoot dry weight reduction of eight feral rye populations ranged from 0.02 to 4.84 g ha^{-1}, indicating high sensitivity of feral rye populations to quizafop-p-ethyl. These preliminary results suggest that the CoAXium™ wheat system can be utilized for effective control of feral rye in Kansas winter wheat production.

Investigating Cross-Resistance to the Synthetic Auxins Fluroxypyr and Dicamba in *Bassia scoparia*. Olivia E. Todd*, Todd A. Gaines, Eric Westra, Phil Westra; Colorado State University, Fort Collins, CO (120)

Fluroxypyr and dicamba are synthetic auxin herbicides used to control *Bassia scoparia* in cereal grains, fallow and rangeland with field use rates of 280 g ai/ha and 560 g ai/ha respectively. Multiple U.S. states have reported dicamba resistance in *Bassia scoparia* and three cases are reported cross-resistant to dicamba/fluroxypyr. A greenhouse fluroxypyr dose response ranging from 0 to 2240 g ae/ha was conducted on three lines: a fluroxypyr resistant line (Flur-R) isolated from an eastern Colorado field survey; a dicamba resistant/fluroxypyr susceptible line (9425); and a dicamba/fluroxypyr susceptible line (S). After two rounds of greenhouse dose response selection and seed bulking of individuals surviving 1x, 2x and 4x fluroxypyr rates, the fluroxypyr resistance trait in flur-R is nearly homogenous. Results from the most recent dose response indicate that the rate required to control 50% of the flur-R population (LD50) was 882 g ae/ha and flur-R was 21 times more resistant than 9425, (pvalue <0.001). To begin investigating cross-resistance in Flur-R, a pilot dicamba dose response (no adjuvant) on the flur-R line caused 50% reduction in growth (GR50) at a rate 1462 g ae/ha. However, only 11 fluroxypyr resistant individuals survived a dicamba dose at 280 g ai/ha or higher. Future directions for this research include repeating the dicamba dose response using NIS, to investigate both previously reported fluroxypyr/dicamba cross-resistance mechanisms and investigate novel mechanisms of resistance using transcriptomics. The result of these dose responses confirms fluroxypyr resistance but whether Flur-R is cross-resistant to dicamba remains unclear.

Herbicide Resistance in Downy Brome. Ian C. Burke*, Rachel J. Zuger; Washington State University, Pullman, WA (121)

Downy brome (*Bromus tectorum* L.) is a wide spread and troublesome weed in wheat (*Triticum aestivum* L.) production and natural areas in the Pacific Northwest (PNW). Downy brome was historically managed mechanically and culturally – growers rotated to spring wheat and tilled fields in the spring when densities were high. Erosion was unacceptable, so over the last 50 years, multiple herbicide modes of action have been introduced to both manage downy brome in wheat and reduce or eliminate tillage. The first herbicides introduced to manage downy brome were trifluralin, a microtubule disruptor, followed by photosystem II inhibitors, initially metribuzin and then atrazine. Diclofop-methyl, an ACCase inhibitor, and chlorsulfuron, an acetolactate synthase (ALS) inhibitor, were introduced in the same period. Most caused injury, required incorporation, or or both, and when safer options were introduced, photosystem II inhibitor use declined, atrazine use stopped, and now only metribuzin remains in moderate use for downy brome management. Glyphosate use in fallow started in the mid-1980's when the cost began to decline, and rates of application have increased with each price reduction. In 1999, the next ALS inhibitor, sulfosulfuron-methyl, was introduced, and in succession, mesosulfuron-methyl, propoxycarbazone-methyl, pyroxsulam, and imazamox were then introduced. Currently, ALS inhibitors are the most commonly used herbicides to manage downy brome in wheat, and glyphosate is used in fallow. Heavy reliance on herbicides has yielded multiple cases of resistance in downy brome. The first case of herbicide resistance in downy brome in the PNW was documented in 1998 when a sulfosulfuron-methyl resistant biotype was found in grass seed fields in Oregon. Diclofop-methyl and quizalofop-p-methyl resistant downy brome was found in a similar system in Oregon in 2005. In a recent survey, of 24 downy brome biotypes from Washington, 14 were resistant to imazamox, 14 were resistant to sulfosulfuron, 12 were resistant to propoxycarbazone-sodium, 10 were resistant to mesosulfuron-methyl, and 15 were resistant to pyroxsulam. Eight were cross-resistant to all ALS inhibiting herbicides. Finally, glyphosate resistant downy brome was found in 2017. Downy brome in the PNW is resistant to all available postemergence and most preemergence herbicides in the PNW, certain types of resistance are now widespread and appears to be conferred by multiple mechanisms.

IAA2 Candidate Resistance Allele on 2,4-D Resistance Mechanism in Indian Hedge Mustard (*Sisymbrium orientale*). Anita Kuepper[1], Marcelo Figueiredo*[2], Christopher Preston[3], Anireddy Reddy[2], Phil Westra[2], Todd A. Gaines[2]; [1]Bayer CropScience, Frankfurt am Main, Germany, [2]Colorado State University, Fort Collins, CO, [3]University of Adelaide, Adelide, Australia (122)

Indian Hedge Mustard (*Sisymbrium orientale*) is an important weed in Australian grain productive areas, causing yield reduction due competition and blocking harvesting equipment due its wire stems. In 2005, a 2,4-D (2,4-Dichlorophenoxyacetic acid) resistant population was identified at South Australia in a cereal field, this population required a dose of 22X to achieve the same levels of control as the susceptible population. On this study, two resistant populations were collected at Port Broughton located 120 Km from Roseworthy, where the susceptible population was collected. The populations were crossed, showing at the F2 generation a segregation of 3 resistant to 1 susceptible. Resistant and susceptible recombinant inbred lines (RILs) were developed by self-crossing F2 plants to reduce genetic background and produce homogeneous, homozygous plants. A RNAseq was performed using 6 resistant and 6 susceptible RILs, Single nucleotide polymorphism and differential expression analysis were performed. A 27 base pair deletion was identified at the auxin receptor IAA2 and it was further confirmed by KASP assay on F5 generation RILs. This deletion is a unique case of 2,4-D resistance, since until now the cases of resistance were associated to SNPs (single-nucleotide polymorphism).

Measuring Combine Facilitated Transport of Italian Ryegrass [*Lolium perenne* L. ssp. *Multiflorum* (Lam.) Husnot] Seed During Wheat Harvest. Kyle C. Roerig*, Andrew G. Hulting, Dan W. Curtis; Oregon State University, Corvallis, OR (123)

Combine harvesters are designed to separate desirable material, such as grain, seeds, and kernels, from undesirable material such as stems, leaves, weed seeds and other foreign material while traveling through the field. The desired material is collected into the grain tank and everything else is typically discharged from the back of the combine into the field. Since this process occurs while the combine is moving, weed seeds entering the combine are typically discharged some distance from where the weed grew, potentially increasing the distance the seeds could travel naturally. Studies were conducted in 2016 and 2017 to assess how far Italian ryegrass seeds could travel during wheat harvest. Seed was prepared for the study by microwaving to prevent germination following the study and dyed to aid in detection and counting. Twenty 0.74m^2 pans were placed 11m apart and wheat harvest was conducted straddling the pans so they remained centered under the combine. At the beginning of each pass thin paper bags containing a total of 5.5kg of one color Italian ryegrass seed were attached to the heads of the wheat. For each pass a different color of Italian ryegrass seed was used. The distribution of three colors were measured in 2016 and four colors in 2017. Since the colors were distinctly different it was not necessary to clean the combine between each color, allowing observations of the previous colors to be made during passes with a subsequent color at a distance of up to 873m. The first pan had an average of 14,220 seeds and the number quickly decreased. By the end of the first pass, at 215m, the pans contained an average of 41 seeds of the color introduced at the beginning of the pass. In pans 774 to 873m from the initial introduction an average of 4.2 seeds per pan were collected, a rate of over 500,000 seeds/ha in the chaff row. These data provide evidence that weed seeds entering a combine during harvest can be transported great distances, readily facilitating the establishment of weed populations across a field from an isolated source from within the field.

Confirmation and Management of ALS Resistant Horseweed (*Conyza canadensis* L.) in Oklahoma Winter Wheat. Jodie A. Crose*[1], Misha R. Manuchehri[1], Todd A. Baughman[2], Vipan Kumar[3], Justin T. Childers[1]; [1]Oklahoma State University, Stillwater, OK, [2]Oklahoma State University, Ardmore, OK, [3]Kansas State University, Hays, KS (124)

Horseweed (*Conyza canadensis* L.) is a common weed in pastures, agricultural fields, and along roadsides in Oklahoma. Although its effect on winter wheat yield has not been quantified, the presence of horseweed plants at wheat harvest can impact harvest efficiency and reduce grain quality. Quelex® (halauxifen + florasulam), Sentrallas® (thifensulfuron + fluroxypyr), and Talinor® (bromoxynil + bicyclopyrone) are three new postemergence herbicides developed for control of broadleaf weeds in winter wheat. These herbicides along with older products were evaluated for their control of horseweed during the spring of 2017 and 2018. Visual weed control was estimated every two weeks throughout the growing season and wheat yield was collected from three of the six site years. Horseweed size ranged from 5 to 20 cm at time of application. Across all site years, halauxifen + florasulam achieved greater than 90% control with the exception of three treatments. Thifensulfuron + fluroxypyr + dicamba achieved greater than 90% control at all site years except one. However, when dicamba was replaced with MCPA, control at all site years was lower. Control with bromoxynil + bicyclopyrone was less than 80% across all site years. Halauxifen + florasulam and thifensulfuron + fluroxypyr were both effective at controlling a wide range of horseweed rosette sizes across all locations while bromoxynil + bicyclopyrone often only resulted in stunting of horseweed. Control of horseweed with treatments other than those mentioned above varied depending on the presence of herbicide resistance, weed size at time of application, and tank mix partner.

Efficacy and Crop Safety of New Broadleaf Herbicide, Haulaxifen-methyl Plus Fluroxypyr, in Northern Plains Spring Cereals. Patti Prasifka*[1], Joe Yenish[2], Mike J. Moechnig[3]; [1]Corteva AgriScience, West Fargo, ND, [2]Corteva AgriSciences, Billings, MT, [3]Dow AgroSciences, Toronto, SD (152)

Arylex™ active (halauxifen methyl), a new active ingredient from Corteva Agriscience™, Agriculture Division of DowDuPont, is a novel synthetic auxin (WSSA group 4) herbicide from the arylpicolinate chemical class being developed for all global cereal markets including the U.S. Pixxaro™ EC herbicide is a newly proposed premix of Arylex and fluroxypyr-meptyl with a target use rate of 6 fl oz/A [Arylex (halauxifen methyl 5.26 g ae/ha) + fluroxypyr-meptyl (123 g ae/ha)] that will be registered in wheat (including durum), barley and triticale. This herbicide offers a unique broadleaf weed control spectrum and favorable crop rotation flexibility for cereals producers. Field research was conducted during the 2017 and 2018 cropping seasons at multiple locations across ND, SD, and MT to evaluate Pixxaro EC efficacy and crop safety in spring wheat. Pixxaro EC was applied with and without tank-mix partners such as 2,4-D ester. Pixxaro EC provided excellent control of redroot pigweed (*Amaranthus retroflexus*), common lambsquarters (*Chenopodium album*), wild buckwheat (*Polygonum convolvulus*), volunteer soybean (*Glycine max*), and kochia (*Bassia scoparia*). Relative to Pixxaro EC alone, the tank mix with 2,4-D ester increased control of waterhemp (*Amaranthis tuberculatis*) and Russian thistle (*Salsola iberica*). There was little to no spring wheat response to Pixxaro EC, indicating excellent crop safety. Pixxaro EC herbicide with Arylex will provide cereal growers with a new tool for controlling many difficult to control broadleaf weeds, including herbicide resistant biotypes of kochia and waterhemp.

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Effects of a Wheat Cover Crop on Weed Control in Corn with Increasing Levels of Irrigation. Randall Currie*, Patrick W. Geier; Kansas State University, Garden City, KS (153)

A killed winter wheat (*Triticum aestivum* L.) cover crop (CC) under limited irrigation has increased corn yield despite the opportunity cost of the water used to grow it (Weed Science, 2005, 53: 709-716). Furthermore, this research showed that a CC can improve weed control. In that study, only two levels of irrigation were possible. Therefore, the main objective of this research was to measure yield and weed control under a broad range of irrigations with and without a killed winter wheat CC. The experimental design was a randomized complete block with four replications in a split-plot arrangement. The main plot factor was irrigation level and CC was sub-plot factor. Six irrigation levels (100, 75, 50, 25, 15, and 0% of full evaporative demand) within each replication were used. Each irrigation level was split into a winter wheat CC portion planted in the fall prior to spring planting and a no CC portion. A wk before corn planting in the spring of 2014, a tank mixture consisting of glyphosate + S-metolachlor + mesotrione + atrazine at 1.4 + 2 + 0.2 + 0.78 kg ha^{-1} was applied over the entire plot area to kill the winter wheat CC and to provide the pre-emergence herbicides for subsequent corn crop. This experiment was repeated in 2015, 2017 and 2018. A planter malfunction in 2017 rendered the after planting data useless. Prior to corn planting, the CC produced a 5- to 20-fold reduction in kochia (*Bassia scoparia* L.) in all years and produced 7- and 31-fold reduction in Russian thistle (*Salsola tragus* L.) in two years and 100% control in 2017 and 2018. Common lambsquarters (*Chenopodium album* L.) was only present in two years and was controlled at 20- and 169-fold prior to corn planting. Averaged over levels of irrigation, CC increased corn yields in all years between 8 and 48% with an average increase of 1857 kg ha^{-1}. The CC often elevated yield in 2014 and 2015, however, this elevation was only significant at the levels greater than 25% of evapotranspiration (ET) and most often at levels higher than 75% of ET. In 2014, yield was described by the equation kg ha^{-1} = 61.1 * % ET + 2184 with a CC (R^2 = 0.76) and kg ha^{-1} = 46.2 * % ET + 1258 in the absence of a CC (R^2 = 0.83). In 2015, although yields across irrigation levels were higher in the presence of CC with a slope of 0.34 for cover and 0.09 for no cover, response to irrigation was less pronounced ($R^2 < 0.43$). In 2018, although CC yields were higher than no-CC yields across irrigation rates, the slopes of these lines were nearly identical; 0.91 and 0.92 for cover and no-cover, respectively. A linear response to level of irrigation was seen in 2018 with R^2 of 0.91 and 0.83 for cover and no-cover, respectively. This suggests that yields might have been less variable in the presence of a CC. These results confirm previous work (Weed Science, 2005, 53: 709-716) and show that the benefits of a killed winter wheat CC to yield and weed control extend over a broad range of moisture conditions but are most pronounced at higher levels of irrigation.

Winter Annual Grass Control with ACCase Tolerant Wheat Production System in Colorado. Eric Westra*[1], Todd A. Gaines[1], Phil Westra[1], Chad Shelton[2]; [1]Colorado State University, Fort Collins, CO, [2]Albaugh, Rosalia, WA (154)

CoAXium is a new ACCase resistant wheat production system (WPS) that allows for post-emergent applications of quizalofop-P-ethyl under the trade name Aggressor for control of winter and spring annual grasses in wheat varieties with the AXigen trait. In addition to the Clearfield production system, CoAXium provides an alternative mode of action and tool for control of the problematic winter annual grasses downy brome (*Bromus tectorum*), jointed goatgrass (*Aegilops cylindrica*), and feral rye (*Secale cereal*e) in Colorado. Field studies with these three winter annual grasses were conducted in 2017 and 2018 to evaluate the impact of application timing, addition of adjuvants, and potential broadleaf herbicide antagonism. CoAXium WPS allows for either fall, spring, or fall/spring split applications of Aggressor depending on fall weed pressure. Spring treatments typically had higher weed control efficacy for all 3 species compared to fall only treatments. Split applications had >96% control for all 3 species and reduced fall and early spring competition with wheat. Adjuvant studies demonstrated the importance of including either NIS at 0.25%, COC at 1%, or MSO at 1% with Aggressor to improve grass weed control efficacy, especially for feral rye. Compared to aggressor alone, the addition of an adjuvant increased feral rye control efficacy by up to 58% for fall applications, and up to 37% for spring applications. Evaluations of broadleaf herbicide antagonism with Aggressor showed that dimethylamine formulations of 2,4-D or MCPA significantly reduced grass weed control efficacy, and these formulations should not be tank mixed with Aggressor. Field studies helped develop and deliver best management practices (BMP) for the CoAXium WPS to Colorado growers. BMP's for the CoAXium WPS were developed to best utilize and sustain this new tool for grass weed control in wheat.

Pinoxaden Plus Fenoxaprop-p-ethyl: The Next Step Up for Grass Control in Wheat and Barley. Pete C. Forster*[1], Brett Miller[2], Donald J. Porter[3], Monika Saini[3]; [1]Syngenta Crop Protection, Eaton, CO, [2]Syngenta Crop Protection, Minnetonka, MN, [3]Syngenta Crop Protection, Greensboro, NC (155)

Pinoxaden Plus Fenoxyprop-p-ethyl (brand name Axial® Bold) is a new selective herbicide developed by Syngenta Crop Protection for postemergence control of annual grass weeds in wheat and barley. The active ingredients contained in Axial Bold are pinoxaden and fenoxaprop-p-ethyl in a 2:1 ratio and they are formulated with the safener cloquintocet-mexyl and a built-in adjuvant. Axial Bold has good crop safety to all varieties of spring wheat, winter wheat and barley. Axial Bold is not approved for use on durum. Axial Bold can be applied from emergence up to the pre-boot stage of spring and winter wheat and emergence to prior to the jointing stage in barley. The use rate of 15 fl oz/A effectively controls wild oat, (*Avena fatua*), foxtails (*Setaria* species), Italian ryegrass (*Lolium multiflorum*), Persian darnel (*Lolium persicum*) and barnyardgrass (*Echinochloa crus-galli*), as well as several other annual grasses. Axial Bold can be tank mixed with broadleaf herbicides for flexible one-pass grass and broadleaf weed control in wheat and barley crops. Field results show that Axial Bold provides more consistent foxtail and barnyardgrass control and more consistent overall grass control when tank mixed with broadleaf herbicides than competitive Group 1 and Group 2 graminicides. Based on its broad grass weed control spectrum, increased activity and consistency, flexibility of use, and crop safety, Axial Bold will become a new standard for grass weed control in wheat and barley crops. Axial Bold is currently approved for use in all wheat and barley growing areas of the U.S. and will be commercialized for the 2019 growing season.

Dichlorprop-p Use in Herbicide Programs for Wheat. Kirk A. Howatt*[1], Joseph E. Mettler[1], Bob Bruss[2]; [1]North Dakota State University, Fargo, ND, [2]Nufarm Americas, Morrisville, NC (156)

The search for alternatives to control broadleaf weeds, especially resistant biotypes, is a perpetual activity. At times this brings our attention to view mature products in a new light. Dichlorprop has been used in lawn premixes to complement and supplement control with other auxinic herbicides. Trials were conducted in North Dakota to evaluate kochia control and antagonism of ACCase-inhibiting herbicide activity with dichlorprop-p in wheat. Dichlorprop-p at 8 oz ae/A provided similar kochia control 1 month after application compared with 2 oz ae/A fluroxypyr, but progression of symptoms was more rapid with dichlorprop-p than fluroxypyr. Yellow foxtail control with fenoxaprop was antagonized by 2,4-D and sulfonylurea herbicides by 10 to 20 percentage points. Dichlorprop-P did not affect foxtail control in most combinations unless sulfonylurea herbicides also were included, which resulted in decreased control by 3 to 8 percentage points. Treatments with 2,4-D reduced fenoxaprop control of wild oat by as much as 15 percentage points 1 month after application. Dichlorprop-p did not reduce wild oat control, but when sulfonylurea herbicide also was included, wild oat control with fenoxaprop was reduced to 93%. Pinoxaden was more resilient to antagonism by broadleaf herbicides. Dichlorprop-p appears to have relevance for broadleaf weed control in small grains and use should be investigated and developed further.

Clopyralid Alternatives for Postemergence Mayweed Chamomile (*Anthemis cotula* L.) Control in Wheat. Rachel J. Zuger*, Ian C. Burke; Washington State University, Pullman, WA (157)

Mayweed chamomile (*Anthemis cotula* L.) is a problematic annual broadleaf weed in wheat crops grown in the high rainfall zones (< 16 inches of average annual precipitation) of the Pacific Northwest (PNW). Yields losses caused by mayweed chamomile are typically less than 5% in winter wheat and up to 25% in spring wheat. There is a growing concern in the PNW for herbicide resistance to clopyralid, a synthetic auxin, and acetolactate synthesis (ALS) inhibiting herbicides. Our objective was to evaluate herbicides of different modes of action in combination for control of mayweed chamomile. Treatments were applied postemergence in early-May to winter wheat and early-June to spring wheat. Treatments contained combinations of ALS inhibitors (florasulam, thifensulfuron, tribenuron, and prosulfuron), synthetic auxins (fluroxypyr, MCPA ester, and clopyralid), 4-HPPD inhibitors (pyrasulfotole and bicylcopyrone), and a photosystem II inhibitor (bromoxynil). Winter wheat studies were conducted in both 2017 and 2018. The spring wheat study was only conducted in 2017. Weed control was assessed by visual estimation at 3 and 6 weeks after treatment (WAT), and studies were harvested in mid-August. In the winter wheat studies, yields did not differ between treatments, although when mayweed chamomile was controlled yields were numerically higher. Brox®-M (MCPA + bromoxynil, Albaugh, LLC) + Starane® Flex (florasulam + fluroxypyr, Dow AgroSciences LLC) resulted in the greatest yield of 97 bu A^{-1} while the nontreated had 86 bu A^{-1}. Widematch® (clopyralid + fluroxypyr, Dow AgroSciences LLC) had the greatest visual control with 81 and 96% at 3 and 6 WAT, respectively. Spring wheat yields also did not differ between treatments, however when mayweed chamomile was controlled yields were numerically higher. Starane® Ultra (fluroxypyr, Dow AgroSciences LLC) + Harmony® Extra (thifensulfuron + tribenuron, FMC Corporation) + MCPA ester had the greatest yield of 65 bu A^{-1} compared to the nontreated with 32 bu A^{-1}. Effective treatments in both winter and spring wheat included Brox®-M + Harmony® Extra, Brox®-M + Affinity® Broadspec (thifensulfuron + tribenuron, FMC Corporation) + MCPA ester, Brox®-M + Peak® (prosulfuron, Syngenta Crop Protection, LLC) + Starane® Ultra, and Starane® Ultra + Harmony® Extra + MCPA ester. In conclusion, there are various herbicide combinations that will effectively control mayweed chamomile. Integrated herbicide systems where multiple modes of action are used to manage the same weed, like those reported here, could help to delay resistance development in weed populations, and could potentially reduce overall weed infestations.

PROJECT 4: TEACHING AND TECHNOLOGY TRANSFER

Philosophy and Weed Management. Joe G. Ballenger*, Andrew Kniss; University of Wyoming, Laramie, WY (114)

Weed management faces difficult challenges in the modern age which range from development of herbicide resistance, a lack of new herbicide modes of action, and societal pushback against herbicides. Novel weed control solutions are needed to supplement our traditional approaches. However, developing effective new practices and technologies will require an understanding of the mechanisms of weed interference. This presentation discusses these mechanisms, and suggests new lines of research which could supplement traditional approaches to weed management.

What Works and Doesn't Work in Managing Herbicide Drift. Robert Klein*; University of Nebraska, North Platte, NE (115)

Dicamba injury began making headlines during the 2017 growing season due to off-target herbicide movement, due to volatilization.

What can applicators can do to mitigate drift? Research shows vapor and particle drift, and sprayer, tank, and transport tank cleanings are important.

"The biggest thing in managing spray particle drift, is wind, wind speed, and wind direction. Always spray in wind speeds between 3 to 10 MPH in a direction away from susceptible vegetation or crops. Doubling wind speed, gives seven times more particle drift 90 feet from the sprayer."

Check wind speed and direction at boom height at start and end of spraying — and when the sprayer is reloaded. WeatherFlow meter records wind speed and direction directly to a smartphone, costing about $90.

There's plenty of discussion on wind speed and particle size, but it’s important to increase application rates when using a larger particle size — at least 15 to 20 gallons per acre, to improve newer dicamba formulations coverage.

Sprayer boom height has largely gone ignored. New dicamba labels require 24 inches of maximum boom height above target pest or crop canopy. "We used to think particle size was more important, but boom height is the second-biggest factor in particle drift. Doubling boom height, from 18 to 36 inches, increases particle drift 3.5 times at 90 feet from the sprayer."

“It's challenging to maintain the correct height with larger booms — some 120 feet or more — unless you have an automatic height controller. Boom height controllers don't work well when traveling faster than 14 mph. They can't react fast enough." Applicators must comply with labels on maximum application speeds.

Several companies have different drift reduction agents or retardants. Not all reduction agents are created equal. Use the cprrect retardant with the right nozzle. Often a different retardant is required with air induction nozzles.

"Newer nozzles, including air induction nozzles, have a pre-orifice where spray solution is measured, with a final orifice making the spray pattern. Compare the pre-orifice size to final orifice size. A big differences in sizes, indicates bigger spray particle. The correct reduction agent can be beneficial with the right nozzle.

Many times a drift retardant pays for itself, with increased pesticide activity. Research has shown as much as a 7% to 8% reduction of fine spray particles which usually provide less control because they either evaporate or move off target.

PROJECT 5: BASIC BIOLOGY AND ECOLOGY

Comparison of EPSPS Tandem Duplication Sequence Across Glyphosate-Resistant *Bassia scoparia* Populations. Todd A. Gaines*[1], Eric Patterson[2], Andrea Dixon[3], Crystal Sparks[1], Karl Ravet[1], Anita Kuepper[4], Phil Westra[1], Joel Felix[5], Don W. Morishita[6], Prashant Jha[7], Andrew Kniss[8]; [1]Colorado State University, Fort Collins, CO, [2]Clemson University, Clemson, SC, [3]Rothamsted Research, Harpenden, England, [4]Bayer CropScience, Frankfurt am Main, Germany, [5]Oregon State University, Ontario, OR, [6]University of Idaho, Kimberly, ID, [7]Montana State University, Huntley, MT, [8]University of Wyoming, Laramie, WY (093)

Glyphosate resistant kochia (*Bassia scoparia*) has been reported across the Great Plains, Intermountain West, Pacific Northwest, and the Canadian Prairie provinces since the first report in Kansas in 2007. Our objective was to ask whether glyphosate resistance evolved once in kochia and spread, or if multiple independent origins of glyphosate resistance occurred over time. We sampled kochia from 45 locations in eight US states and 1 Canadian province, and used 11 polymorphic Simple Sequence Repeat (SSR) markers developed from whole genome sequencing data. Results from the SSR data were inconclusive as to single or multiple origins of glyphosate resistance, as very high levels of within population genetic diversity were detected and no clear patterns of relatedness across populations were evident. In a separate approach, we assembled the duplicated genomic region containing the EPSPS gene. This revealed two types of repetitive units of different sizes, each containing EPSPS and several other genes, as well as a mobile genetic element-containing sequence inserted near the EPSPS gene. We used these sequence features as markers. Population analysis revealed that all southern Great Plains samples shared the same EPSPS repeat structure and mobile genetic element, while different patterns observed in kochia samples from northern Wyoming, Oregon/Idaho, and Canada suggested that independent origins of glyphosate resistance could be possible in each location.

Regional Differences in Kochia Germination from the US Great Plains: Effect of Temperature. Ramawatar Yadav*[1], Prashant Jha[1], Andrew Kniss[2], Nevin C. Lawrence[3], Gustavo M. Sbatella[4]; [1]Montana State University, Huntley, MT, [2]University of Wyoming, Laramie, WY, [3]University of Nebraska-Lincoln, Scottsbluff, NE, [4]University of Wyoming, Powell, WY (094)

Development of glyphosate- and ALS-resistant kochia across the US Great Plains is a serious concern for producers, especially in sugar beet-based crop rotations due to a lack of alternative chemistries to control kochia in sugar beet. Therefore, there is an urgent need to implement ecological weed management strategies. This requires improved understanding of regional differences in kochia germination patterns (Objective 1) and using that information to design ecological strategies to deplete kochia seed banks (Objective 2). To fulfill objective 1, experiments (two runs) were conducted in 2018 at the MSU-SARC, Huntley, MT to quantify germination characteristics of 44 kochia accessions collected from north (Huntley, MT; Powell, WY) and south (Lingle, WY; Scottsbluff, NE) region. Eight different temperatures from 4 to 26 C were evaluated. An event-time, 3-parameter log-logistic model was used. Optimum germination temperature for kochia accessions ranged between 14.5 C and 26 C. At the lowest temperature (4 C), kochia from north took less time to achieve 50% germination (<3 d) than those from south. Also, kochia from north had higher percent cumulative germination (≥95%) than those from south at 4 C. However, no regional differences in germination pattern were observed at temperatures from 11.5 C to 26 C. Therefore, a stale seed bed approach may be more effective in the south region to stimulate kochia germination early in the spring and exhaust the seed bank using tillage or non-selective herbicides prior to late-planted crops such as dry bean grown in rotation with sugar beet.

Multiple Mechanisms of Dicamba Resistance in Kochia (*Kochia scoparia*). Mithila Jugulam*[1], Junjun Ou[2], Sushila Chaudhari[1], Hugh J. Beckie[3]; [1]Kansas State University, Manhattan, KS, [2]University of California, Davis, Davis, CA, [3]University of Western Australia, Perth, Australia (095)

Kochia is one of the topmost troublesome broadleaf weeds in the US Great Plains. Dicamba is widely used for kochia control. However, the recent and rapid evolution of dicamba resistance in North American Great Plains is a major threat to manage this weed. Previously we reported reduced translocation of dicamba contributing to resistance in kochia from CO. More recently, a two nucleotide change in a highly conserved degron region of *IAA16*, which is crucial for auxin binding and interaction between the TIR/F-box and AUX/IAA proteins was also found responsible for dicamba resistance in this population. However, in a dicamba-resistant (DR) kochia population from KS, reduced uptake, translocation or increased metabolism of dicamba was not found to confer resistance. In this research we investigated a) if any alterations at the potential target site(s) of dicamba may be involved in resistance to dicamba in DR kochia from KS and b) the physiological basis of dicamba resistance in DR kochia from Alberta, Canada along with the dicamba-susceptible (DS) populations. Presence of single nucleotide polymorphisms (SNP) and overexpression of a gene family of auxin receptors (TIR/AFB protein complex) was investigated in DR Kochia from KS. Using ^{14}C dicamba, uptake, translocation or metabolism of dicamba was determined in DR kochia from AB. The results of this study indicate the presence of a SNP in one of the TIR1 homologs in several DR-kochia plants. Although, co-segregation of this SNP with DR phenotype needs further investigation. Interestingly the DR kochia from AB showed a reduced uptake without any alteration in translocation or metabolism of dicamba. Overall, these results confirm naturally evolved resistance to a single herbicide in the same weed species.

Integrating Crop Diversity, Cover Crops, and Targeted Grazing to Manage Wild Oat and Kochia. Mei Ling Wong*[1], Fabian Menalled[1], Larson Christian[1], Patrick Carr[2], Tim Seipel[1]; [1]Montana State University, Bozeman, MT, [2]Montana State University, Moccasin, MT (096)

Wild oat and kochia are problematic weeds in cereal crops of the Northern Great Plains, especially as the frequency of multiple herbicide resistant biotypes has increased. Though there is a need to develop integrated control measures there is little information on how weeds respond to different tactics. In 2018, at Montana State University's Central Agricultural Research Center we conducted an integrated weed management experiment to test kochia and wild oat response (biomass and seed production) to ten treatments: spring wheat height (short and tall levels) each sown at two densities (67 kg/m2, 101 kg/m2), lentils, tilled fallow, two forage-crop combinations (spring barley and pea, winter triticale and pea) terminated using sheep grazing and haying. We found that wild oat biomass and seed production was highest in the lentil treatment and declined in response to wheat density. Timing of forage crops harvest affected how much and wild oat regrew. The later termination reduced wild oat seed production in wild oat, but not kochia. Kochia biomass and seed production were highest in the tilled fallow and winter-pea triticale, and lowest in the wheat. Kochia performance was unaffected by wheat density and height, or forage crop termination method. Overall, our findings suggest that the timing of management practices and crop affected both species but in different ways. Therefore, integrated management plans must consider the weed, the crop, and sequence of the crop rotation in order to understand weed population dynamics and maximize benefits of integrated weed management.

Integrating Kochia and Palmer Amaranth Biology, Molecular, and Biochemical Findings into Management Strategies. Phil Westra*[1], Todd A. Gaines[1], Eric Patterson[2], Andrew D. Effertz[1]; [1]Colorado State University, Fort Collins, CO, [2]Clemson University, Clemson, SC (097)

Colorado crop producers are now faced with 2 of the most difficult to control broadleaf weeds, both of which are resistant to glyphosate due to the novel mechanism of gene amplification. Kochia and Palmer amaranth are prevalent in most of the eastern agricultural region while kochia has been widespread in Colorado for more than 50 years during which time it has also developed resistance to ALS, triazine, and PGR herbicides. Research at CSU is focused on the physiology, biochemical, and molecular bases for the rapid evolution of resistance in these two weeks. State-wide surveys have produced 8 years of seed samples used to monitor resistance evolution over time. Molecular evaluation of gene amplification in kochia now allows refined assessment of glyphosate resistance on a spatial scale. Additional research continues to evaluate novel approaches for the control of these 2 weeds in Colorado.

Novel Dicamba Resistance Mechanism in *Bassia scoparia*. Neeta Soni*[1], Eric Patterson[2], Cristiana T. Argueso[1], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Clemson University, Clemson, SC (098)

Herbicide resistance evolution frequency to synthetic auxins herbicides such as dicamba is occurring at lower rate compared to other modes of action. However, a shift in this trend is expected due to an increase commercialization of genetically modified tolerant crops to these herbicides. A dicamba and glyphosate resistant *Bassia scoparia* population from Akron, CO (named “M32”) was identified as part as a resistance survey in 2012, but its resistance mechanism remains unknown. Our main objective is to identify the molecular mechanism that confers resistance to dicamba in the M32 *B. scoparia* population. A dose response experiment was conducted to characterize the M32 population resistance level. The reported target site and non-target site mechanism in *B. scoparia* were investigated. Fifty-eight M32 plants were genotyped for the reported G127N mutation in the auxin co-receptor IAA16 using Sanger sequencing. Chalcone synthase expression was measured using quantitative PCR and flavonols quantification was conducted using a LC-MS/MS. Dose response results showed the M32 *B. scoparia* population can survive a dicamba rate equivalent to 2X (560 g ae ha^{-1}) label rate in cereals. No evidence of mutation G127N in the sequenced region were identified. Additionally, no difference in chalcone synthase overexpression and flavonols production compared to susceptible populations were identified. These results suggested that the M32 population contain a novel dicamba resistant molecular mechanism. Future research will include an assessment on auxin co-receptors and differential gene expression analysis to identify the candidate gene(s) involved in dicamba resistance.

Efficacy of Cultural, Mechanical, and Chemical Weed Control for Proactive Herbicide Resistant Weed Management. Elizabeth G. Mosqueda*[1], Andrew Kniss[1], Nevin C. Lawrence[2],

Prashant Jha[3], Gustavo M. Sbatella[4]; [1]University of Wyoming, Laramie, WY, [2]University of Nebraska-Lincoln, Scottsbluff, NE, [3]Montana State University, Huntley, MT, [4]University of Wyoming, Powell, WY (099)

Combination of cultural, mechanical, and chemical weed management practices are underused in many cropping systems, particularly for herbicide-resistant weed management. Kochia (*Bassia scoparia*) is problematic for growers throughout the Western United States, in part, because of evolved resistance to numerous herbicides. Field studies were conducted from 2014 through 2017 at sites in Wyoming, Montana, and Nebraska in order to quantify the combined impacts of crop rotation, tillage, and herbicide use on the evolution of ALS-resistant kochia. A known proportion of ALS-resistant kochia was established in 2014 before imposition of treatments. Tillage (main-plot) included annual intensive tillage or minimum tillage. Crop rotations (split-plot) consisted of continuous corn, corn-sugarbeet, corn-dry bean-sugarbeet, and corn-dry bean-small grain-sugarbeet. Herbicide treatments (split-split-plot) included complete reliance on ALS inhibitor herbicides, mixtures including ALS inhibitors, or an annual rotation which included ALS herbicides. Kochia densities were estimated each summer by counting the number of kochia plants within a randomly placed m^2 quadrant per plot. Data was analyzed using a linear mixed effects model. All main effects (tillage, crop rotation, and herbicide) affected kochia density ($P<0.001$). Kochia densities were typically lowest in more diverse crop rotations (corn-dry bean-small grain-sugarbeet, corn-dry bean-sugarbeet, corn-sugarbeet) and treated with an ALS herbicide mixture throughout the duration of the study. In addition, plots which were annually intensively tilled usually contained lower kochia densities on average compared to plots that were minimally tilled throughout each year of the study.

Establishment of Pollinator-Friendly Flora Following Cheatgrass Control. Nicholas DiMascio, Janet Hardin, Arathi H. Seshadri*; Colorado State University, Fort Collins, CO (100)

Paper withdrawn

Rhizomatous Bud Response to Growth Regulator Applications in Field Bindweed (*Convolvulus arvensis* L.). Jeremy R. Thompson[1], Lynn M. Sosnoskie[2], Ian C. Burke*[1]; [1]Washington State University, Pullman, WA, [2]University of California - Davis, Davis, CA (101)

Root bud release mechanisms in perennialized field bindweed (*Convolvulus arvensis* L.) remain largely unknown. Hormones clearly play a role; for example, gibberellic acid promotes root growth, cytokinins inhibit root growth, and brassinosteroids can promote growth at low concentrations and inhibit growth at high concentrations. Studies were undertaken to describe the response of field bindweed bud dormancy to exogenously applied hormones as compared to mechanical bud removal and herbicides. Prior to the initiation of the trials, greenhouse studies were conducted to determine the time to perenniation (as determined by the production of regenerative root buds) for seedling field bindweed. Measured by root excavation, successful perenniation was determined to occur at 10 weeks. For the greenhouse dormancy release trial, plants were treated with increasing doses of cytokinin (as Seacrop 16), gibberellic acid (as Pro Gibb LV), brassenosteriod (as Organic Vitazyme), 2,4-D (as Weedone LV4), dicamba (as Clarity), and aminocyclopyrachlor (as Method 280 SL). Of the growth regulators, gibberellic acid promoted the greatest bud release as measured by aboveground biomass. Dicamba and aminocyclopyrachlor reduced biomass with increasing dose, or completely controlled the bindweed, depending on rate. 2,4-D increased above ground biomass at low doses, and reduced biomass at high doses. Gibberellic acid appears to be a potential tool for inducing bud release in perennialized field bindweed, and future work will focus on using gibberellic acid in field studies to manage field bindweed when integrated with other management strategies.

Role of Glutamine Synthetase Isoforms and Herbicide Metabolism in the Mechanism of Resistance to Glufosinate in Italian Ryegrass Biotypes from Oregon. Caio Augusto Brunharo*[1], Hudson K. Takano[2], Carol Mallory-Smith[3], Franck Dayan[2], Brad Hanson[1]; [1]University of California - Davis, Davis, CA, [2]Colorado State University, Fort Collins, CO, [3]Oregon State University, Corvallis, OR (102)

Recently, glufosinate-resistant *Lolium perenne* L. spp. *Multiflorum* biotypes from Oregon were identified, exhibiting resistance levels up to 2.8-fold the recommended field rate. One biotype (MG) exhibited an amino acid substitution in the enzyme glutamine synthetase 2 (GS2), whereas the other (OR) did not. We hypothesized that the amino acid substitution in GS2 is involved in the mechanism of resistance to glufosinate in MG, and that non-target-site mechanisms of resistance are present in OR. Enzyme activity, homology modelling, gene expression quantification, herbicide mobility and stability experiments were performed with MG, OR and a known-susceptible biotype. OR metabolized glufosinate faster than the other two biotypes, with >75% of the herbicide metabolized in OR, compared to approximately 50% in MG and the susceptible biotypes. A mutation in the GS2 co-segregating with resistance in MG did not reduce the enzyme activity, results further supported by our enzyme homology models. This research supports the conclusion that a metabolism mechanism of glufosinate resistance is present in OR, but suggests that other mechanisms are also present in Oregon *Lolium perenne* L. spp. *Multiflorum* biotypes.

The Influence of Light Reflected from Three *Amaranthaceae* Species on Growth and Development of Winter Wheat. Osama S. Saleh*; University of Wyoming, Laramie, WY (103)

Reflected light from plant canopies has a reduced red (R) to far-red (FR) ratio. Plants can sense the changes in R:FR in their surroundings and initiate physiological and morphological responses (shade avoidance) which may affect their growth. A large pail field study was conducted in 2018 to evaluate the response of winter wheat (*Triticum aestivum* L.) to reflected light from neighboring weeds. There were three treatments: kochia (*Bassia scoparia* (L.) A.J. Scott), common lambsquarters (*Chenopodium album* L.), and redroot pigweed (*Amaranthus retroflexus* L.) arranged in a randomized complete block design with 12 replicates. Neighboring plants were grown in separated containers from winter wheat, so there was no root interaction. The light intensity of red $_{655\text{-}665\ nm}$ and far-red $_{725\text{-}735\ nm}$ were used to calculate R:FR ratio for the reflected light. Common lambsquarters had the least R:FR (0.076) compared to the kochia (0.12) and redroot pigweed (0.15). There were no differences in chlorophyll concentration among treatments. Reflected FR light from kochia, common lambsquarters, and redroot pigweed reduced the number of tillers (33, 41, and 59 % respectively) and leaves as (31, 36, and 57% respectively) in winter wheat. In addition, there was 54, 59 and 72% reduction in wheat biomass in kochia, common lambsquarters, and redroot pigweed treatments, respectively. Kochia and redroot pigweed promoted elongation of winter wheat stems by 12%.

Physiological Basis for the Contact Activity of Glufosinate. Hudson K. Takano*[1], Roland Beffa[2], Phil Westra[1], Franck Dayan[1]; [1]Colorado State University, Fort Collins, CO, [2]Bayer, Frankfurt, Germany (104)

Glufosinate targets glutamine synthetase (GS), a key enzyme for nitrogen metabolism and photorespiration. Unlike other amino acid biosynthesis inhibitors, glufosinate is a fast-acting herbicide with limited translocation. Our objective was to investigate the physiological basis for the contact activity of glufosinate. Two series of experiments were performed using palmer amaranth (*Amaranthus palmeri*) as a model species. Initially, we developed a method to quantify glufosinate translocation through xylem and phloem. Then, physiological and biochemical responses were evaluated in plants treated and untreated with glufosinate. Leaf translocation was 43% acropetal and only 4% basipetal, indicating that glufosinate has good xylem translocation but limited phloem mobility. Photosynthetic electron flow and carbon assimilation were completely inhibited, and ammonia accumulated at high levels following GS inhibition by glufosinate. Inhibition of GS caused a massive and rapid light-dependent generation of reactive oxygen species (ROS). The free radical formation led to accumulation of malondialdehyde, a product of lipid peroxidation, supporting the hypothesis that ROS triggers the fast action of glufosinate. Based on these facts, we suggest that inhibition of GS blocks both photorespiration and the Calvin Cycle, two major sinks for the energy generated by the light reactions. Under these circumstances, the excess of electrons is transferred to molecular oxygen, which generates ROS, the causal agent of lipid peroxidation and rapid cell death. We conclude that ROS accumulation and limited phloem mobility form the physiological basis for the observed contact activity of glufosinate.

The Effects of Elevated Temperature and CO_2 on *Ventenata dubia* and *Bromus tectorum* Seedling Growth. Audrey J. Harvey*[1], Jane Mangold[1], Lisa J. Rew[1], Tim Prather[2]; [1]Montana State University, Bozeman, MT, [2]University of Idaho, Moscow, ID (116)

Impacts of climate change are expected to alter the abundance and distribution of invasive annual grasses, such as *Ventenata dubia* (ventenata) and *Bromus tectorum* (downy brome), further impacting range and natural areas. High temperature extremes will be more frequent for longer time periods and increased atmospheric CO_2 is expected to double across all ecosystems even in the most conservative estimates. Climate change draws concern for the potential success of winter annual grasses in arid and semi-arid plant communities. Information on *B. tectorum*'s biological response to climate change in laboratory and field experiments are available for monocultures, however, more knowledge is needed on response when growing with other grasses, including other invasive grasses like *V. dubia*. A replacement design series was used to determine differences in seedling growth for *V. dubia* and *B. tectorum* growing alone and in combination under current (4 ˚C/23 ˚C at 400 ppm CO_2) and elevated (10.6 ˚C/29.6 ˚C at 800 ppm CO_2) climate conditions. There was one trial per climate scenario with 10 replications per competition type (inter-, intra-specific competition for each species). *Bromus tectorum* was bigger than *V. dubia* across climate and competition treatments, but contrary to previous findings, both species grew smaller in elevated conditions. *Ventenata dubia* allocated more growth to its roots than *B. tectorum*, and this difference remained consistent across both climate conditions, indicating *V. dubia* may have a competitive advantage at elevated conditions.

The Effect of Management System on Weed Communities During a Transition to Organic Farming. Larson Christian, Fabian Menalled, Tim Seipel*; Montana State University, Bozeman, MT (117)

Incorporating livestock grazing into farming systems to manage weeds and terminate cover crops has the potential to reduce tillage, especially in organic farming systems prone to erosion. At the Montana State University's Fort Ellis Researcher Center we conducted a five year cropping experiment to evaluate weed community responses (biomass, species richness, and community composition) to three farming systems. The farming systems included: a conventional no-till system that used herbicides to manage weeds, a tilled organic system that relied on tillage for weed control, and a grazed organic system that used sheep grazing to reduce tillage. Each system had the same crop rotation (1-safflower, 2-sweet clover, 3-winter wheat, 4- lentil, 5- winter wheat), and each crop phase was present in each year from 2013 to 2017. We analyzed the effects of farming system through time and crop phase using linear mixed-effects models and ordination. We found a significant farming system-year interaction for weed biomass, species richness, and species composition. Weed biomass and richness did not differ among farming systems in 2013 and 2014, but in the final three years (2015-2017) biomass was significantly higher in the grazed organic and species richness was lower in the conventional no-till. In 2013 and 2014, species composition was similar among farming systems but diverged beginning in 2015. The sweet clover crop phase had the highest weed biomass and richness, lentil and safflower phases had similar intermediate values, and the winter wheat phases had the lowest means for both response variables. The crops that overwintered in the field (i.e. wheat and clover) had similar weed species composition, and spring planted crops (i.e. safflower and lentil) had more similar species composition. Our results demonstrate that using grazing to reduce tillage results in a more abundant but more diverse weed community compared with traditional farming systems. Further, we found weed biomass and composition is affected by crop phase and farming system, and that different farming management systems can result in different weed communities within two years.

Drones for IDing Drift - Comparing Visible Injury and Spectral Response of a Simulated Drift Experiment. Chloe M. Mattilio*, Daniel Tekiela, Elizabeth G. Mosqueda; University of Wyoming, Laramie, WY (118)

When an herbicide drifts from intended targets to nearby susceptible vegetation, significant injury can occur. This non-target drift has been problematic in the Southern United States with synthetic auxin herbicides damaging adjacent crops. When presented with a suspected drift case, injury must first be determined to be from an herbicide, then the source of the herbicide must be identified, as applicators are responsible for damages. But drift can be difficult to identify without spatial context, so we propose unmanned aerial system (UAS) remote sensing to compare plant health at the field level. The research presented compares remote detection and visual injury estimates of dry bean in a simulated herbicide drift experiment using three synthetic auxins applied at full recommended use rates, a 25% rate, a 4% rate, and a 1% rate. Proportional visual injury estimates and multispectral imagery of each bean plant were collected multiple days after herbicide application, and normalized difference vegetation index (NDVI) was calculated to quantify changes in spectral reflectance of plants. NDVI was then reversed to 1 – NDVI, so spectral injury and visual injury could be compared on a scale from 0 (low injury) to 1 (high injury) with linear regression. All herbicides and rates reduced visible and spectral health, and remote sensing detected injury at rates comparable to visual estimates. UAS remote sensing shows promise for diagnosing plant injury due to non-target herbicide drift, providing efficient and continuous data to compare full fields quickly, so herbicide source can be determined.

SYMPOSIUM: Integrated Pest Management Research in the West

Low-Cost IPM for Medusahead and a Cost-Benefit Framework to Support Adoption. Jeremy J. James*; University of California Cooperative Extension, Browns Valley, CA (125)

The invasive grass medusahead (*Taeniatherum caput-medusae*) dominates millions of acres of rangeland across the West. While the ecological impacts of medusahead on rangeland ecosystem function have been well demonstrated the economic impacts of this species are poorly understood and many tools available to control this and similar species are relatively expensive to apply. Here we quantify the effects of medusahead abundance on beef cattle gains and evaluate the potential of using grazing and low rates of aminopyralid to control medusahead in a cost-effective manner. We stocked pastures with different levels of medusahead abundance with steers from March to beginning of May in both 2016 and 2017. There was little evidence that medusahead abundance influenced average daily gain ($P > 0.05$) but across both years increasing medusahead abundance reduced carrying capacity. At low rates of aminopyralid application and grazing we reduced medusahead seed by viability by 95% resulting in large reductions in cover the second goring season. We present an online calculator that can take these results on economic impact and evaluate how various IPM treatments may potentially create a net benefit for agricultural production. Together these data allow land managers access to a low-cost tool to control medusahead and identify when treatment benefits will exceed costs.

An Integrated Weed Management Approach for Controlling Kochia in Wheat Using Physical and Cultural Tactics. Stephen L. Young*; Utah State University, Logan, UT (126)

Weeds affect production systems by reducing yields, impeding harvest operations, and increasing the soil weed seed bank. In conventional systems, herbicides are most commonly used to control weeds, yet efficacy is declining for some of the most challenging weeds, like kochia. Therefore, finding alternative ways to enhance the competitive ability of crops is critical in limiting the growth of weeds and their detrimental effects on production systems, while maintaining available tools. In field studies, an integrated approach that included cultural and chemical tools was used to determine effects on kochia in irrigated spring wheat. After one year, results indicated a cover crop was as effective as herbicides and persisted through to the end of the season, even under reduced or no irrigation. Incorporating a more diverse set of practices into an irrigated wheat crop could prove useful for controlling kochia and maintaining effectiveness of available herbicides.

Enhanced Implementation of the Online Soil Solarization Forecasting Model. Carol Mallory-Smith*[1], Jennifer Parke[1], Len Coop[1], Lloyd Nackley[2]; [1]Oregon State University, Corvallis, OR, [2]Oregon State University, Aurora, OR (127)

Solarization employs solar radiation to heat the soil under a transparent plastic film to achieve temperatures detrimental to certain soilborne pathogens and weed seeds. Most solarization studies have been conducted in warm climates, but recent advances in plastic film technology made soil solarization feasible in regions with cooler climates such as the Pacific Northwest. In 2016-2017, we conducted pre-plant soil solarization trials in three Oregon tree nurseries. We found reductions in soil populations of plant pathogens and weeds, and increased growth of the subsequent crop in solarized treatments relative to a non-solarized control. We developed an online model http://uspest.org/soil/solarize for growers to estimate the time necessary to solarize soil based on their farm location, start date, and target pest. The model uses data from local weather stations to forecast soil temperatures using solar radiation and air temperature data. The model predicts the time necessary to kill target weed seeds and plant pathogens based on results from controlled environment studies. Soil solarization is a cost-effective, non-chemical approach to IPM that potentially could be applied to other Pacific Northwest cropping systems such as organic vegetables and berry crops.

Testing Community Functional Composition of Vegetation Buffers to Improve Post-Fire Invasion Resistance of Coastal Sage Scrub. Travis Bean*; University of California - Riverside, Riverside, CA (128)

As wildfires in the West become more frequent and severe, disturbances from firefighting activity may provide opportunities for invasive species to establish and spread. Detailed characterization of risky landscape features like fire breaks, as well as improved postfire rehabilitation strategies, are needed to address this challenge. Postfire competitive seeding has been historically difficult and inconsistent, but by carefully designing the composition of species mixes used for competitive seeding in fire breaks, managers may be able to improve seeding outcomes. At Chino Hills State Park, fire breaks left by bulldozers during the Canyon fires of 2017 may have spread Mediterranean grasses and invasive forbs into Coastal Sage Scrub. Reestablishing native vegetation by seeding native species in these fire breaks may provide invasion resistance and help prevent type conversion of CSS to annual grassland. A greenhouse experiment at UC Riverside has characterized key competitive traits of twenty native and five invasive species from Coal Canyon.

Using these data we have created one seed mix with similar traits to invaders, and the other with maximum functional dispersion in competitive traits across the local native species pool. We hypothesize that the trait-matched seed mix will reduce relative abundance and dispersal of invasive species in the first year after seeding due to intense resource competition, but that the high functional dispersion community will have better native plant establishment in the second year due to improved stress tolerance of slower-growing species. We will use our findings to provide better guidelines for landmanagers tasked with rehabilitating burned areas with bulldozer lines.

Integrating Mechanical or Chemical Control with Biological Control for Improved Saltcedar Management at Southwestern Reservoirs. Erik A. Lehnhoff*, Leeland Murray, Carol A. Sutherland, Amy Ganguli, Brian J. Schutte, Leslie Beck; New Mexico State University, Las Cruces, NM (129)

Invasive shrubs such as *Tamarix* spp. are ecological and economic threats in the United States Southwest and West as they displace native vegetation and often require expensive management. *Tamarix* control typically consists of chemical and mechanical removal, but these methods may have negative ecological and economic impacts. Tamarisk leaf beetles (*Diorhabda* spp.) released for biocontrol have become established within many Western river systems and can provide additional control. Previous *Diorhabda* research has studied integration of beetle herbivory with fire, and intensive mechanical management methods, but little research has been conducted on integration with low soil disturbance methods such as aboveground mowing and foliar herbicide application to improve management. Our research at Caballo Reservoir in southern New Mexico addressed the question, could *Diorhabda* herbivory be combined with mechanical and chemical treatment to achieve greater control with fewer non-target impacts? We integrated mowing and foliar imazapyr herbicide at standard (3.6 g ae L^{-1} (0.75% v/v) and low (1.2 g ae L^{-1} (0.25% v/v)) rates with herbivory. Treatments were replicated five times at two sites – a dry and seasonally flooded site. Green foliage and gas exchange rates (via LI-COR 6400) were measured. Mowing and full herbicide rates reduced green foliage and limited re-growth compared to low herbicide rate and beetles alone, but did not affect photosynthesis or transpiration on the per-plant level. Integrating conventional management such as mowing and herbicide with biocontrol could improve *Tamarix* management by providing stresses in addition to the herbivory alone.

SYMPOSIUM: Rights-of-Way – Beyond Integrated Vegetation Management to Integrated Habitats!

The Vision "Beyond IVM to Integrated Habitat". Sandra K. McDonald*; Mountain West Pesticide Education & Safety Training, Fort Collins, CO (158)

Rights-of-way (RoW) are distinct management zones including roadsides, railways, power lines, oil and gas pipelines, ditch banks, and other rights-of-way. Historically, RoW were managed exclusively for safety; often noxious weeds were only managed because of the legal requirement. Now RoW are being utilized for recreation and as corridors that connect natural landscapes and improve habitat conditions for certain wildlife. "Habitat connectivity" has become the new buzzword among RoW utility managers. Managing RoW for biodiversity is more complicated than managing for safety. RoW managers are planting pollinator and wildlife friendly vegetation. It is important that invasive weed management remain front and center of the discussion and decision process. It is also vital that weed managers understand the changing goals of RoW management. Weed managers have become accustomed to the public concerns with the safety and environmental impact of using herbicides and other management strategies to manage undesirable vegetation. Yet, RoW managers are being told not to mow because of the detrimental impact on nesting birds and other wildlife. Now RoW managers are being asked to plant pollinator attractive species without any knowledge of potential invasiveness. Therefore, RoW remain a major distribution vector of invasive weeds.

Integrated Management to Enhance Pollinator Habitat, Wildlife Habitat and Desirable Species Composition. Rick Johnstone*; Integrated Vegetation Management Partners, Newark, DE (159)

Integrated Vegetation Management Partners has documented plant community changes on electric, natural gas and highway rights-of-way across the United States as vegetation management transitioned from routine cutting to integrated vegetation management, including the selective use of herbicides. The decline of bees and the Monarch butterfly prompted a Federal Strategy on Pollinators and the potential listing of several pollinator species under the Endangered Species Act. To evaluate and qualify the value of botanical communities to insect pollinators, a Pollinator Site Value Index (PSVI) was developed. This paper summarizes plant community changes in various ecosystems of the United States and applies our PSVI to measure their relative value to *Apis* and *Bombus* bees, and to Lepidopterans.

What's the "Ideal World" for Pollinators – What Do They Need to Survive/Thrive. Arathi H. Seshadri*; Colorado State University, Fort Collins, CO (160)

Globally, pollinators continue to face challenges resulting from wide spread habitat loss, pests and diseases and rampant use of agrochemicals. It is necessary to consider sustainable practices at every step of the way to make this planet more habitable to all organisms specifically pollinators that are directly responsible for our food and health. What does an 'ideal world' for pollinators look like? The presentation will focus on understanding who these pollinators are, their diversity and role in our ecosystem, and factors that directly contribute towards their conservation and sustainability. I will also discuss the targeted efforts to improve habitats for pollinator habitats. I will present some of the results of our ongoing studies on importance of nutritional diversity for pollinators and relate that to ways in which we can improve the aesthetic value of our environment for human health.

"Real World" Needs and Purpose(s) of the Rights-of-Way. Liza Rossi*; Colorado Parks and Wildlife, Steamboat Springs, CO (161)

Paper withdrawn

Various Purposes of Rights-of-Way Provide Constraints and Opportunities. Lindy Garner*; US Fish and Wildlife Service, Denver, CO (162)

Paper withdrawn

Managing Right-of-Way with Vehicles from all Across the County in a National Park Highly Susceptible to Invasion. Sue Mills*; National Park Service, Yellowstone National Park, WY (163)

Paper withdrawn

Noxious Weeds in Rights-of-Way Habitat – A Regulatory Perspective. Slade Franklin*; Wyoming Department of Agriculture, Cheyenne, WY (164)

A noxious weed regulator's perspective. Control of noxious weeds must remain a priority and a legal requirement. Rights-of-way not only support wildlife and pollinator habitat but they are noxious weed corridors. Is this shift in focus to habitats going to result in a reduction in noxious weed management as a priority?

Interstate Highway 76 is the "Colorado Pollinator Highway". Michael Banovich*; Colorado Department of Transportation, Denver, CO (165)

Colorado House Joint Resolution 17-1029, which designated I-76 from mile marker 1 to 183 as the "Colorado Pollinator Highway". Pursuant to this House Joint Resolution, the Colorado Department of Transportation (CDOT) is managing the right-of-way to promote pollinator habitat on I-76. CDOT is also developing a statewide Integrated Roadside Vegetation Management program, which will address pollinator habitat management for other highway corridors; it is intended that once the program is developed, the scope of this Procedural Directive may be broadened at that time.

Plants Appropriate for Rights-of-Way. Irene Shonle*; Colorado State University, Black Hawk, CO (166)

Native plants can be a great choice for rights of ways. They can be low-maintenance, provide a connected habitat for pollinators and birds, and are well-adapted to local conditions. Considerations include height, salt tolerance and drought tolerance. We will also briefly discuss how to distinguish some native plants that are good ROW plants that are commonly mistaken for noxious weeds.

Reclamation and Seed Mixes Post Highway Disturbance. Michael Banovich*; Colorado Department of Transportation, Denver, CO (167)

Abstract not available

Using Herbicides to Release Native Species for Rights-of-Way Habitat. Shannon L. Clark*[1], Scott J. Nissen[2]; [1]Colorado State University, Fort Collins, CO, [2]Colorado State University, Ft Collins, CO (168)

Rights-of-way are widespread in the US, with paved roads alone covering over 4.3 million km, and have become a vector for the spread of weeds. Herbicides are the most commonly used tool for weed control on rights-of-way because they are cost effective and time efficient. Oftentimes, selective herbicides that provide long-term weed control are desired for rights-of-way applications to allow for native species recovery or release. Several herbicides approved for use on rights-of-way can negatively affect native species, while the duration of weed control can be highly variable. Therefore, herbicide options are needed that provide multi-year control without negatively impacting the native plant community. Indaziflam is a newer herbicide option for pre-emergent weed management on rights-of-way. Studies have shown that native perennial species are tolerant to indaziflam applications, and in several cases an increase in native species has been observed. It has also been shown that tank-mixes including indaziflam can extend broadleaf weed control compared to aminocyclopyrachlor or picloram applied alone. Picloram and aminocyclopyrachlor, commonly used on rights-of-way for broadleaf weed control, can reduce native forbs and shrubs, although in sites with dense weed infestations forb and shrub abundance are oftentimes more impacted by the invasion and less impacted by herbicide applications. Increases in warm-season grasses with aminocyclopyrachlor treatments have been observed in some sites, while picloram treatments tended to increase cool-season grasses. On rights-of-way with a remnant native plant community, the multi-year weed control provided by indaziflam may allow enough time to achieve native species recovery. With the addition of herbicides like picloram or aminocyclopyrachlor for broadleaf weed control, there could be a temporary reduction in native forbs and shrubs, although the weed control provided by these herbicides can assist in the release of native perennial grasses.

Rights-of-Way Herbicide Applicator Issues. Daniel C. Cummings*; Corteva Agriscience, Bonham, TX (169)

Right-of-way herbicide applications are uniquely visible to the public and commonly find scrutiny beyond agriculture-based herbicide applications. To be successful, managers and applicators must look beyond the right of way to identify challenges and potential issues. This presentation will look at several key aspects of right of way herbicide applications including herbicide selection and application implementation, herbicide resistance management strategies, and mitigation of off-target movement and non-target injury. I will address and identify controllable and non-controllable aspects of herbicide applications. In addition, I will discuss plant identification and herbicide use for specific weed targets. We will also discuss EPA regulations regarding grazing tolerances and use sites. I will discuss planning and implementation of mitigation strategies for herbicide off-target movement. Specific topics include mitigation team development, utilization, and use of rapid public personality evaluations to aide in addressing concerns for specific interested parties. Within this discussion we will look at a few real-world case studies of applicator issues and the resulting mitigation plans and resolutions. Corteva Agriscience is committed to helping applicators and land managers find success in their vegetation management programs through product stewardship, trusted partnerships, and excellence in technology transfer and training.

DISCUSSION SESSIONS

Project 1 Discussion Session: Weeds of Range, Forest, and Natural Areas

Co-Moderator: Derek Sebastian, Bayer, Fort Collins, CO, Harry Quick, Bayer, Fort Collins, CO

Due to an oversight during development of the meeting program, no discussion session was scheduled for this project in 2019. Near the end of the meeting, the session chair, co-chair and interested parties had a brief ad hoc discussion of the Range, Forest, and Natural Areas presentation sessions and elected Shannon Clark from Colorado State University to serve as chair-elect in 2020.

Chair (2020): Harry Quicke, Bayer CropScience harry.quicke@bayer.com

Co-Chair (Chair 2021): Shannon Clark, Colorado State University shannon.clark@colostate.edu

Nominations of a new Chair-Elect:

Shannon Clark is the new Chair-Elect for the Range, Forest, and Natural Areas Project of WSWS.

Chair 2019:
Derek Sebastian, Bayer, 2114 18th Street Road, Greeley, CO 80631
derek.sebastian@bayer.com

Chair-Elect 2020:
Harry Quicke, Bayer, 1140 Shore Drive, Windsor, CO 80550
harry.quicke@bayer.com

Chair-Elect 2021:
Shannon Clark, Colorado State University, 380 Aurora Way, Fort Collins, CO 80525
shannon.clark@colostate.edu

List of Attendees not available

Project 2 Discussion Session: Weeds of Horticultural Crops

Moderator: Marcelo Moretti, Oregon State University, Corvallis, OR

Topic: *Can the Academic Entrepreneurial Spirit Spur Novel Weed Control Methods? How Weed Scientists Can Help Shape the Future of Weed Control in Horticulture Crops.*

For the 2019 meeting, the weeds of horticultural crops section had 11 paper presentations that were well attended with up to 40 participants at one time. The discussion session occurred on Wednesday, March 14 from 9:30 to 11:00 am local time. The discussion topic title was "Can the Academic Entrepreneurial Spirit Spur Novel Weed Control Methods? How Weed Scientists Can Help Shape the Future of Weed Control in Horticulture Crops". Moderator: Marcelo L Moretti, OSU.

The discussion was initiated by a short presentation made by the moderator. Attendants were guided through a thought process with the objective of recalling examples of innovative weed control methods in different areas of weed management methods (preventative, biological, mechanical, cultural, or chemical). Upon identification of examples of innovative weed control methods, the group discussed if the given examples of research and development were initiated in the public sector, private sector, or a combination of both. In most of the cases listed, the private sector leads the discovery efforts while the public sector was involved in the development or testing of the novel methods. Most of the participants indicated that academia is better prepared to work on the development of methods as the discovery is a much longer path and often requires multi-disciplinary collaboration and considerable capital investment.

The following question was how to proceed with the research efforts in the academic world, as a single institution or multi-institution efforts. A few of the positive sides of multi-institution effort was the increased likelihood of success in securing funds, a broader scope of work, and possible quicker development process. The major drawbacks of multi-institution collaborative efforts were the limitation of sharing research equipment if geographically distant or by similar seasonality of work. Additionally, the concerns of intellectual property were raised. Despite the challenges intrinsic to multi-institutions efforts, the consensus was that it is probably the best way forward to achieve significant progress.

The potential role that Western Society of Weed Science could play in the multi-institution efforts was questioned. One idea proposed was the creation of "Task forces" based on weed control strategies rather than cropping system (e.g. robotics weed control vs vegetable weed control with robotics). This approach may allow continuity of previous research efforts and facilitate knowledge transfer among researchers. Additionally, ways to promote participation of non-weed scientists in these projects and by doing diversifying the audience of the WSWS meeting and the type of work presented at the meeting.

Finally, the discussion was concluded with concrete action tasks for the next moderators. For the 2020 WSWS meeting, the Horticultural section will propose a symposium to discuss robotics in Horticultural crops inviting researchers, companies, intellectual property specialists, and funding agencies representatives (USDA, NSF). The symposium will facilitate the communication of all parts involved in robotics and hopefully spur novel weed control methods.

A business meeting was conducted at the end of the discussion session, and Dr. Harlene Hatterman-Valenti, from North Dakota State University, was selected as the chair-elected for the 2020 meeting and becoming the Horticulture chair in 2021. Jesse Richardson is content to serve as the Weed of Horticultural chair for the 2020 meeting in Maui, Hawaii.

Chair 2019:
Marcelo Moretti, Oregon State University, 4017 AG Life Sciences Bldg, Corvallis, OR 97331
marcelo.moretti@oregonstate.edu

Chair-Elect 2020:
Jesse Richardson, Corteva, 9846 Lincoln Ave, Hesperia, CA 92345.
jesse.richardson@corteva.com

Chair-Elect 2021:
Harlene Hatterman-Valenti, North Dakota State University, PO BOX 6050, Dept. 7670, Fargo, ND, 58108-6050
h.hatterman.valenti@ndsu.edu

Attendees:

Name	**Affiliation**	**Email address**
Jesse Richardson	Corteva	jesse.richardson@corteva.com
Larissa Larocca	Oregon State University	larissa.larocca@hotmail.com
Harlene Hatterman-Valenti	North Dakota State University	h.hatterman.valenti@ndsu.edu
John Roncoroni	University of California ANR	jaroncoroni@ucanr.edu
Brian Schutte	New Mexico State University	bschutte@nmsu.edu
Joel Felix	Oregon State University	joel.felix@oregonstate.edu
Ronald Edward Peachey	Oregon State University	peacheye@hort.oregonstate.edu
Kai Umeda	University of Arizona	kumeda@cars.arizona.edu
Andrew Kniss	University of Wyoming	akniss@uwyo.edu
Erik Augerson	Oregon State University	augersoe@oregonstate.edu
Joseph Wood	New Mexico State University	joewood@nmsu.edu
Pat Clay	Valent	pat.clay@valent.com

Project 3 Discussion Session: Weeds of Agronomic Crops

Moderator: Vipan Kumar, Kansas State University, Agricultural Research Center-Hays, KS

Topic: *Herbicide-Resistant Weeds in the West: Current Status and Path Forward*.

The problem of weed species developing herbicide resistance in agronomic crops across the western U.S. was discussed among WSWS members. During the first half of the session, the topic was mainly focused on understanding the current state of herbicide-resistant weeds in the western U.S. The group members identified and endorsed the severity of the problem ranging from pacific northwest (PNW) to northern and central Great Plains states. The academic researchers pointed out that herbicide resistance in weeds is location and species specific. The consensus was made that herbicide resistance in grassy weeds (feral rye and downy brome) are more problematic under dryland production in PNW states; whereas, resistance in broadleaf weed species (Kochia, Palmer amaranth, Horseweed, and Russian thistle) is of main concern in the Great Plains states. Kochia and wild oats were identified as key species manifesting herbicide resistance in southern Canadian provinces. The group members from industry emphasized that economic situation of growers plays a key role in driving herbicide resistance issue. It was also mentioned that the WSWS Herbicide-Resistant Plants Committee is planning to conduct a Qulatric Survey on the current state of herbicide-resistant weed species from the member states.

In the latter half of the session, the discussion was focused on potential future research and outreach avenues as path forward to mitigate the problem of herbicide-resistant weeds in the western U.S. The idea of integrated weed management (IWM) systems, including chemical, non-chemical, and use of herbicide-resistant crop technologies was brought up and discussed. The group acknowledged that more research is needed on incorporating tillage, cover crops, competitive crop rotations, and precision ag tools for weed control in the western U.S. A brief discussion echoed around the use of cover crops as weed control tool and for animal grazing; however, concern was raised on limited soil moisture available to grow cover crops in the semi-arid dryland production of western U.S. Among other IWM ideas, identifying competitive crop cultivars and maintaining susceptible weed populations were also briefly discussed. General consensuses on moving forward were studying and showing the economic benefits of using these IWM based weed control tactics to the western growers which can help them to adopt those strategies. Towards the end of the session, Kirk Howatt nominated Joseph Ikley from North Dakota State University as chair-elect for the 2020 annual meeting. With no other nominees, Joe was unanimously elected as chair elect.

<u>Chair 2019:</u>
Vipan Kumar, Kansas State University, 1232 240 Ave, KSU Ag Research Ctr, Hays, KS 67601
vkumar@ksu.edu

<u>Chair-elect 2020:</u>
Misha Manuchehri, Oklahoma State Univeristy, 371 Agricultural Hall, Stillwater, OK 74078
misha.manuchehri@okstate.edu

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

List of Attendees not available

Project 4 Discussion Session: Teaching and Technology Transfer

Moderator: Kirk Howatt North Dakota State Univeristy, Fargo, ND

Topic: *It's a bird. It's a plane. It's a quadcopter?*

This session explored how drones are currently being used in weed science and the fit as a tool in research and management. The session started with short presentations by researchers at NDSU, followed by various audience members form industry and academia sharing their work with drones. Topics included various applications of the technology across agriculture and wildland weed management.

Members of the audience were using drones in agricultural settings for plant identification, weed mapping, assessing crop health, optimizing spray applications, evaluating research plots, and differentiating herbicide resistant biotypes of the same species (temperature and reflectance). Various sensors from Lidar to NDVI to heat sensors were being utilized in the projects. Audience members working in invasive weed management currently had been focused on species mapping and differentiation from desirable vegetation. Members in the audience were having some success and generating useful information utilizing drones as a tool.

Through the discussion numerous difficulties with using this technology were expressed. A common concern was being promised too much or over-selling the capabilities of remote technologies. Utilizing imagery collected requires a lot of processing power and software to stich images together for functionality. It is a lot of computer work, after the drone flights have been made, in order to analyze the data and produce a functional product. There was consensus that for many drone applications, utilizing hand crews may still be more efficient. This is possibly truer for wildland areas than in the consistent structure of agricultural land. With current limitations and challenges with the technology, drones may not be saving time for many applications.

While machine learning and plant identification may be the future, current technologies are limited in their scope. Differentiating crops from weeds is entirely feasible, but individual species identification in agricultural fields and in rangelands is very difficult. Species morphology, developmental differences through the season, and various environmental conditions introduce substantial variability that can confound and complicate the establishment of reliable and consistent results. Generally, there was consensus within the discussion that there is still a long way for the technology to progress before it will be entirely functional for identification. Users also expressed issues with the resolution of various sensors and the ability to produce useful images at the proper scale without flying too low. Flying low reduces the window of observation resulting in more flight time to cover a given area. With the level of current technology there may be opportunity for drones to be more functional in small-plot research than as a field weed management tool.

Concerns were raised that many companies/firms may be overselling their products ability to provide plant identification services. Additionally, there was discussion of a disconnect between weed scientists and people developing drones and drone software for use in weed management. For example, companies had made claims that drones could be used to detect invasive weeds for early detection and rapid response. But in reality, they were only effective in detecting patches of plants, not individuals. Establishment of the patches reduced the benefit for early detection. Manual scouting might be more capable of discerning early establishment, but as a trade-off for acres inspected. Even finding large patches has not been as successful as proposed because of the variable landscape and multiple species with similar appearance. Likewise, on the agronomic side, there was disconnect between the need and understanding of acceptable weed control. People designing the software did not understand that a number of escaped weeds in a field would be unacceptable, even if the majority of weeds were controlled.

Utilizing drones to physically spray herbicides was mentioned at several points throughout the session. One company is currently exploring the possibility of using drones to make pesticide applications over tall corn. Another company was using both small and large drones for various pesticide applications. Researchers in the room expressed the ability to put out research plots in rough terrain with drones, to ease application. Downsides of using drones for pesticide application included droplet size requirements of some pesticides and difficulty achieving adequate coverage because of the limitation in spray tank volume. Even with these limitations, there are situations where drones could functionally increase productivity.

Use of robot systems to weed or spray in plots and fields was brought up. Many were aware that products are available, but no one in the room had direct activity with them. An advantage there is complete autonomy once parameters are established, at least according to promotion material. They have made greatest advances for areas of total vegetation management where species identification is not a concern. But they can operate any time weather and field conditions permit.

The audience in the session came to a general consensus that there is much potential for drones as tools in weed science and weed management. However, there is still a lot of work to do to further the practicality/usefulness of the technology. For remote sensing and operations to be successful, there needs to be more joint efforts/knowledge among geospatial/computer skills, system equipment, and weed science.

Chair-elect:
Kirk Howatt will be next years section chair and Scott Nissen nominated Thomas Getts (tjgetts@ucanr.edu) from California for chair elect and he was elected.

Chair 2019:
Kirk Howatt, North Dakota State Univeristy, PO BOX 7670, Fargo, ND 58108
kirk.howatt@ndsu.edu

Chair-elect 2020:
Thomas Getts, UCCE, 707 Nevada Street, Susanville, CA 96130
tjgetts@ucanr.edu

Chair-elect 2021:
Chris Mayo, Bayer CropScience, 625 Plum Creek Circle, Gardener, KS 66030
christopher.mayo@bayer.com

Attendees:

Name:	Affiliation	Email Address:
Daniel Abe		
Phil Banks	Marathon Ag Consulting	marathonag@zianet.com
Pat Clay	Valent U.S.A. LLC	pat.clay@valent.com
James Dollins	U.S. Forest Service	jdollins@fs.fed.us
Jeanne Falk Jones	Kansas State University	jfalkjones@ksu.edu
Tom Getts	UCCE	tjgetts@ucanr.edu
Stott Howard	Syngenta Crop Protection	stott.howard@syngenta.com
Kirk Howatt	North Dakota State University	kirk.howatt@ndsu.edu
Christie Hubbard Guetling	University of Idaho	hubb5924@vandals.uidaho.edu
James Jackson	Texas A&M	jamesr.jackson@ag.tamu.edu
Robert Klein	University of Nebraska	Rklein1@unl.edu
Drew Lyon	Washington State University	drew.lyon@wsu.edu
Dean Maruska	Bayer Crop Science	dean.maruska@bayer.com
Chloe Mattilio	University of Wyoming	cmattilio@uwyo.edu
Chris Mayo	Bayer Crop Science	christopher.mayo@bayer.com
Mike Ostlie	North Dakota State University	mike.ostlie@ndsu.edu
Corey Ransom	Utah State University	corey.ransom@usu.edu
Jesse Richardson	Corteva	jesse.richardson@corteva.com
Roland Schirman	Wash State University-retired	schirman@innw.net
David Spak	Bayer Crop Science	david.spak@bayer.com
Daniel Tekiela	University of Wyoming	dtekiela@uwyo.edu
Darren Unland	BASF	darren.unland@basf.com

Project 5 Discussion Session: Basic Biology and Ecology

Moderator: Albert Adjesiwor, University of Wyoming, Laramie, WY

Topic: *Incorporating Ecological Principles into Weed Management Decisions.*

Understanding weed ecology and biology is fundamental to successful weed management. This discussion section focused on core research areas and future research needs, barriers to conducting long-term ecological studies, as well as suggestions on approaches to long-term ecological studies in weed science. The discussion began with participants emphasizing that weed ecology must be viewed as an integral part of weed management. However, there was a consensus that research (especially long-term studies) on weed ecology and ecological principles, and how incorporating ecological principles into weed management decisions may influence farm profit is generally lacking. Research on weed emergence timing, long-term studies on soil quality and weed seedbank dynamics, time after flowering to viable seed production, the effect of light on weed seed germination, and weed seedbank longevity, were identified as core areas of focus in weed ecology that could be incorporated into weed management decisions. Participants also mentioned that future research must strive to understand weed traits and identify the traits that are hard to evolve, the effect of diversified cropping systems on weed management, and weed response to environmental change.

It was proposed that studies on weed response to environmental change must focus on what would become limited in the future. An example was cited from the Middle East where weed science studies are becoming increasingly focused on the effect of moisture stress on weed dynamics. One important issue that came up was the increasing research focus on a few problematic weeds (e.g. kochia, waterhemp, and Palmer amaranth) with less focus on weed shifts. It was proposed that in managing problematic weeds (especially herbicide resistant weeds), there is the need to evaluate weed shifts and assess which weeds are likely to become the next problematic weeds once the current dominant weed is successfully managed.

Despite the importance of weed ecology and ecological principles in weed management, some participants felt there is less interest in weed ecology research because of the stigma of not doing “smart” research. Some weed scientists think that doing basic biology and ecology research is seen by their peers as “not smart”. In addition, weed ecology studies tend to be “long-term” in nature and this has also contributed to declining interests. Long-term ecology studies need dedicated personnel, land, funding (difficult to come by), and commitment. Thus, most faculty (especially tenure-track faculty) tend not to be interested in these kinds of studies.

Even where there is scientific evidence that ecological principles are important in weed management, farmers are hesitant to adopt ecological-based practices because of short-term profitability and economic sustainability concerns. One additional issue raised was that we are not doing a good job at convincing stakeholders of the need for ecological studies and potential benefits of incorporating ecological principles into weed management decisions. It is also very difficult to explain to stakeholders (especially policy makers) that all weeds are not the same.

The discussion led to how to conduct long-term studies that could be incorporated into weed management decisions. One proposed solution is collaboration with tenured faculty and other universities and scientists (e.g. soil fertility and microbiologists) for long-term funding and continuity of weed ecology studies. It was also mentioned that some Agricultural Experiment Stations, farmers, and institutions such as USDA- Agricultural Research Service (ARS), Natural Resources Conservation Service (NCRS), and Global Biodiversity Information Facility (GBIF), collect long-term data that could be used to study the effects of management on weeds and how that knowledge could be incorporated into weed management decisions. There is an urgent need to educate farmers and other stakeholders on the importance of incorporating ecological principles into weed management decisions and how this could reduce reliance on herbicides and mechanical weed control. Incentives for the adoption of ecological-based weed management could improve adoption of such practices.

Chair 2019:
Albert Adjesiwor, University of Wyoming, Dept 3354, 1000 E University Ave, Laramie, WY 82071
aadjesiw@uwyo.edu

Chair-elect 2020:
Caio Brunharo, Oregon State University, Crop Science Bldg, Corvallis, OR 97331
Caio.brunharo@oregonstate.edu

Chair-elect 2021:
Neeta Soni, Colorado State University, 300 W. Pitkin, Fort Collins, CO 80523
neeta.soni@colostate.edu

Attendees:

Name:	**Affiliation**	**Email Address:**
Nevin Lawrence	University of Nebraska-Lincoln	nlawrence2@unl.edu
Carol Mallory-Smith	Oregon State University	carol.mallory-smith@oregonstate.edu
Tim Seipel	Montana State University	timothy.seipel@montana.edu
Brad Hanson	University of California-Davis	bhanson@ucdavis.edu
Caio Brunharo	Oregon State University	caio.brunharo@oregonstate.edu
Audrey Harvey	Montana State University	audrey.harvey@student.montana.edu
MeiLing Wong	Montana State University	meiling.wong@student.montana.edu
Steve Sauer	Boulder County	ssauer@bouldercounty.org
Noelle Orloff	Montana State University	noelleorloff@montana.edu
Michelle Majeski	Montana State University	michellemajeski@montana.edu
Don Morishita	University of Idaho	don@uidaho.edu

Tanner Hart	University of Wyoming	mhart12@uwyo.edu
Lesley Beckworth	Teton County Weed and Pest	lbeckworth@tcweed.org
James Jackson	Texas A&M AgriLife Extension	JamesR.Jackson@ag.tamu.edu
Steven Seefeldt	Washington State University	seefeldt@wsu.edu
John Spring	Colorado State University Ext	john.spring@colostate.edu
Becka Hendricks	University of Idaho	rwilliamson@uidaho.edu
Josh Shorb	Park County Weed & Pest	jsharb@parkcountyweeds.org
Jake Jarret	Park County Weed & Pest	jake@parkcountyweeds.org
Bob Finley	Park County Weed & Pest	rfinley@dteworld.com
Maha Haidar	American University of Beirut	mhaidar@aub.edu.lb
Jane Mangold	Montana State University	jane.mangold@montana.edu
Joseph Ballenger	University of Wyoming	jballeng@uwyo.edu
Albert Adjesiwor	University of Wyoming	aadjesiw@uwyo.edu

WESTERN SOCIETY OF WEED SCIENCE NET WORTH REPORT

April 1, 2018 through March 31, 2019

ASSETS	
Cash and Bank Accounts	
American Heritage Checking	$67,244.56
American Heritage Money Market	$101,874.12
CD#3	$25,463.95
CD#4	$25,351.23
CD#5	$25,477.26
CD#6	$25,603.60
CD#7	$25,730.26
TOTAL Cash and Bank Accounts	$296,744.98
Investments	
RBC Dain Rauscher Account	$194,643.42
TOTAL Investments	$194,643.42
TOTAL ASSETS	$491,388.40

WESTERN SOCIETY OF WEED SCIENCE CASH FLOW REPORT

April 1, 2018 through March 31, 2019

INFLOWS ($)	
Annual Meeting Income	82,026.78
Capital Gains	1,599.75
Interest Income	3,241.80
Dividend Income	1,144.89
Membership Dues	2,400.00
Royalty for Proceedings Or RPR	900.00
Security Value Change	-516.38
Student Travel Account	4,021.00
Sustaining Member Dues	19,400.00
Weed Control In Natural Areas	600.00
Publications Royalties	505.93
TOTAL INFLOWS	115,323.77
OUTFLOWS ($)	
Annual Meeting Activities	51.00
Annual Meeting Filing Fee	190.07
Annual Meeting App	2,750.00
Annual Meeting Expense	48,612.38
Bank Charge	17.00
Book Handling Fee	377.40
Books	233.00
CAST Annual Dues	1,500.00
Copies	35.50
Director of Science Policy	6,117.97
Fee Charged	2406.06
Insurance	800.00
Management Fees	21,883.00
Merchant Account	2,507.23
Miscellaneous	33.10
Proceedings/Publications	750.00
Postage	326.24
Summer Meeting	5,652.00
Student Awards	5,454.16
Supplies	724.29
Taxes	835.00
Travel to Summer Meeting	1,025.78
Travel to WSWS Meeting	68.95
Web Site Hosting	4,000.00
Society for Advancement of Chicanos/Hispanics and Native Americans in Science Conference	1,650.00
TOTAL OUTFLOWS	108,000.13
OVERALL TOTAL	$7,323.64

WSWS 2019 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.

Joe Yenish

Dr. Joe Yenish received degrees at North Dakota State University (BS), University of Wisconsin-Madison (MS) and North Carolina State University (PhD).

Joe came west after two years in a postdoctoral position at Univ of Minnesota and never looked back. He had a successful research and extension program at Washington State University as associate professor from 1996 to 2010. Growers benefited from his research on the ecology and biology of crops and weeds in dryland rotations and subsequent management strategies. He specifically worked on grain legumes, dry peas, lentils, and chickpeas as well as supporting timothy hay, grass for seed, canola, mustard, camelina, and other crop species. Joe joined Dow Agrosciences in 2010 as a field scientist where he continues research with a primary focus on weed control and nitrogen stabilization in cereal protection.

He provides technical service, training, and education for U.S. cereals crop protection products and advises the Cereals Portfolio Leader and Product Manager with biological and agronomic information for the development and positioning of U.S. cereals products.

Joe gets around the West as he supports Northern Plains and Pacific Northwest Sales Districts which include MN, ND, MT, WY, ID, UT, NV, OR, WA.

He was awarded Research and Development awards from his company in 2014 and 2015 as well as Above and Beyond in 2012, 2014, and 2015.

Among all that, Joe provided great service to the Western Society of Weed science. He and his graduate students presented papers almost annually. He served on the board as Research Section and Education and Regulatory Chairs and served as President 2015-2016. Multiple times, Joe served as student paper judge, helped facilitate annual meetings, and served on committees.

A quote from one of his letters of support: “As the former president of the WSWS, I can remember many times where Joe provided leadership on issues and provided thoughtful input into the society’s future vision.”

Drew Lyon

Dr. Drew Lyon received degrees from University of Illinois (BS) and University of Nebraska, (MS and PhD).

His early career included Technical Service Representative for American Cyanamid Company and Assistant County Extension Advisor at the University of Illinois until he joined University of Nebraska in Research and Extension in 1990. He had a successful career as Professor of Agronomy & Horticulture until 2012.

Drew then became the first weed scientist awarded the Endowed Chair, Small Grains, Extension and Research, Weed Sciences at Washington State University. His research includes weed control in dryland small grain production systems of eastern Washington including crops grown in rotation with small grains and summer fallow. Integrated weed management is the primary focus and research results are quickly transferred to Washington growers through his Extension program.

From a supporting letter, “In addition to his service to weed science, Dr. Lyon is a solid resource for the farmers in the state of Washington and is accessible through the WSU small grains website, his podcast and grower presentations.”

He has published a book, seven book chapters, 86 journal articles, 88 extension publication, 10 software releases, and serves as Associate Editor Weed Technology. Drew has received 17 honors and awards including Western Society of Weed Science Outstanding Weed Scientist.

Drew has authored or co-authored papers for the WSWS annual meeting just about every year since 1993 and has submitted papers to the WSWS Research Progress Reports. Service to the Western Society of Weed Science includes Weeds of Agronomic Crops Chair, Research Section Chair, numerous committees, and Drew has served as WSWS President.

WSWS 2019 HONORARY MEMBER

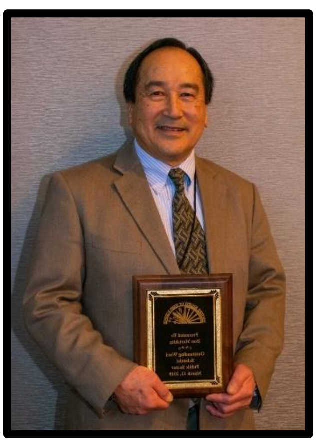
This award was not conferred in 2019

WSWS 2019 OUTSTANDING WEED SCIENTIST AWARDS

Todd Gaines

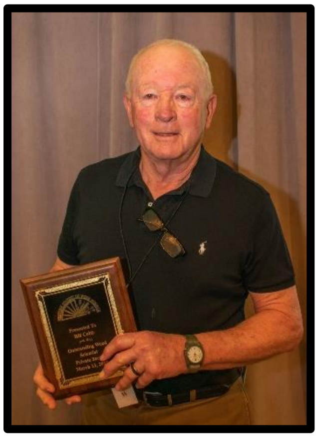
The Outstanding Weed Scientist, Early Career was awarded to Todd Gaines. Dr. Todd Gaines is an assistant professor in the Department of Bioagricultural Sciences and Pest Management at Colorado State University. His specialization is in molecular weed science and functional weed genomics. He completed his PhD in weed science at CSU, followed by post-docs in Western Australia (University of Western Australia, Australian Herbicide Resistance Initiative) and Germany (Bayer CropScience, Weed Resistance Competence Center). His research goal is to support sustainable weed management in cropping systems. Projects in his research group include identifying the molecular and genetic basis of herbicide resistance mechanisms and other genetic traits in weeds and developing rapid molecular diagnostics for herbicide resistance. Todd Gaines has distinguished himself as a very productive and collaborative molecular weed scientist with an outstanding publication record and has mentored 7 graduate students in his program.

Don Morishita



The Outstanding Weed Scientist, Public Sector was awarded to Don Morishita, University of Idaho, Kimberly, Idaho. Dr. Don Morishita is a Professor of Weed Science, Extension Specialist, andSuperintendent of the University of Idaho Kimberly Research and Extension Center. He received his BS degree from Utah State University and MS and Ph.D. degrees in weed science from the University of Idaho. He began his career in Weed Science at the Kansas State University Southwest Kansas Research Extension Center in 1986. He returned to Idaho in 1990 to join the faculty at the University of Idaho Twin Falls Research and Extension Center. His research and extension responsibilities have focused on integrated weed management in sugar beet, dry bean and small grain cropping systems. His proudest contributions to agriculture has been the work on direct seed sugar beet production and utilizing narrow row planting, as well as his extensive research on cover crops and direct seeding for dry bean production. In the 32 years of his professional career, Dr. Morishita has established himself as an outstanding scientist and a reliable source of technical information to growers, policy makers, colleagues, and the agricultural industry. He has authored or coauthored 112 refereed journal articles/peer reviewed extension bulletins, 5 book chapters, 100 abstracts, and numerous articles on weeds and their control in popular press. Don has served as a major/co-major advisor to 18 graduate students.

Bill Cobb



The Outstanding Weed Scientist, Private Sector was awarded to Bill Cobb, Cobb Consulting Services, Kennewick, Washington. Dr. William (Bill) Cobb received a BA in Biology, chemistry minor from Eastern Washington University in 1964. He served in US Military from1964-1972. His received a PhD in Plant Pathology at Oregon State University in 1973. From 1970 to 1974, he worked as Manager and staff agronomist at Sun Royal Co. where he conducted field scale trials on potatoes for nematode, disease, and perennial weed control. He then spent 14 years as a Senior Research Scientist for Lilly Research Laboratories/Elanco Products Co. field screening pesticides in major and minor crops grown in the Pacific Northwest. In 1988, Bill started Cobb Consulting Services that includes agronomic consulting and problem solving for large commercial growers, contract research, and GLP assistance for support of EPA labeling of pesticides on food crops. He has served the WSWS by initiating and contributing to two symposia, presenting 18 papers, serving on the board of directors, elected to Education and Regulatory position, and serving on committees for a total of 18 years combined.

WSWS 2019 WEED MANAGER AWARD

This award was not conferred in 2019

WSWS 2019 PROFESSIONAL STAFF AWARD

Traci Rauch

Traci Rauch completed her bachelor's degree in Biology at Pacific Lutheran University in 1992 and her Master of Science degree at the University of Idaho in 1998. Traci started her career in weed science as a Scientific Aide in 1995 and is currently a Research Associate at the University of Idaho. She conducts field and greenhouse experiments in the agronomic weed science program. Traci has been an active member in the Western Society of Weed Science since 1993. She has authored/coauthored 236 WSWS Research Progress Reports, 29 WSWS Proceedings Abstracts, 7 other professional abstracts, 3 Weed Technology articles, and has been WSWS Proceedings co-editor for 6 years, and WSWS Research Progress Report editor or co-editor for 8 years. She has presented at 145 other meetings and field tours. Growers and industry personnel seek her out for consultation on weed control in wheat, legumes, seed crops and other commodities. She has helped train graduate students at the University of Idaho since the mid-1990's.

WSWS 2019 PRESIDENTIAL AWARD OF MERIT

Sandra McDonald

Sandra McDonald received the WSWS Presidential Award of Merit from Andrew Kniss at the 2019 annual meeting in Denver, Colorado.

WSWS 2019 ELENA SANCHEZ MEMORIAL STUDENT SCHOLARSHIP RECIPIENTS

The recipients of the Elena Sanchez Memorial Scholarship for 2019 were Larissa Larocca de Souza (MS student, Oregon State University), Ramawatar Yadav (PhD student, Montana State University), and Lucas Kopecky Bobadilla (MS student, Oregon State University). A big thanks to their advisors for bringing along such great promising talent for the future of weed science.

WSWS 2019 RITA BEARD ENDOWMENT STUDENT SCHOLARSHIP RECIPIENTS

The Rita Beard Endowment Foundation Board of Trustees has selected four recipients of travel scholarships for 2019. They are Christie Hubbard, an M.S. student at the University of Idaho; Rory O'Connor, a Ph.D. candidate at Kansas State University; Rachel Seedorf, an M.S. student at Colorado State University; and Travis Sowards, a Ph.D. student at Brigham Young University. The Rita Beard Endowment Foundation is a 501 (c) (3) non-profit that was created from a generous donation by Rita Beard's family and friends. Funds are awarded to support educational opportunities of students and early career invasive species managers by providing registration and travel to professional meetings including Society for Range Management, Western Society of Weed Science, Western Aquatic Plant Management Society and the North American Invasive Species Management Association. Christie Hubbard and Rachel Seedorf will be attending the Western Society of Weed Science annual meeting in March, and Rory O'Connor and Travis Sowards will attend the Society for Range Management annual meeting in February. To read more about the Foundation, learn how to apply for the 2020 scholarships, or make a donation go to: **http://www.wsweedscience.org/rita-beard-endowment-foundation/**.

Christie Hubbard Guetling

I started my journey to becoming a weed scientist by investigating the ability of a native parasitic plant, dodder, to suppress the vigor of Johnsongrass. This broadened my knowledge of invasive plants, parasitic plants, and experimental design. The experiment led to a plant survey opportunity in Costa Rica where I learned the art of plant identification. The research demonstrated the importance of human intervention after catastrophe (natural or manmade). I am currently using aerial imagery and GIS tools to build plant community susceptibility models for a portion of the Greater Yellowstone Ecosystem to focus ground survey efforts on susceptible areas. My professional ambition is to minimize invasive species impacts and restore habitats to functioning, native communities.

Rory O'Conner

I became interested in invasive species management during my range management class of my undergraduate program. The following summer I worked for the USDA-ARS in Burns, OR, as a rangeland aid on juniper expansion. In graduate school, I have worked on becoming an invasion rangeland ecologist. During my M.S. degree, I studied how annual grass invasions in the Great Basin and Mojave Desert occur after fire. I decided to return to investigating woody plant encroachment for my Ph.D., but to elucidate drivers and mechanisms of encroachment in the tallgrass prairie. I see myself working in the federal government and with land owners/managers to answer questions and solve problems by creating collaborative, science informed, land management prescriptions.

Rachel Seedorf

Having grown up on a farm and ranch, I have been surrounded by agriculture my whole life and understand the challenges that invasive plants can present to land managers in many different settings. I have grown more interested in the dynamics of natural area landscapes, as well as the biology of the weeds and the effects herbicides have on them. My own research involves working closely with Denver International Airport to help develop an invasive management plan. As a municipality that owns 50 square miles, there is a challenge to maintain the landscape in a timely and effective manner. The environment is continually changing, and I hope that through any career path I have taken, I will be able to continue learning and informing others about the importance of managing invasive plants in all kinds of natural areas.

Travis Sowards

John Muir observed that earth's organisms are so entangled that we cannot understand a single entity without studying the entirety of the system in which it is found. The seed of land stewardship had been planted, cultivated through my life experiences, and has blossomed into a deep desire to understand and care for degraded ecosystems. The experiences I gained in Hawaii with the US Forest Service opened my eyes to the detrimental impacts that invasive exotic species can have on native ecosystems. My Ph.D. research has focused on seed enhancement technologies to provide greater restoration success. I am developing both theoretical knowledge and practical skills in restoration ecology that I believe will enable me to provide novel perspectives of the interrelated complexities of ecological restoration, conservation of natural resources, and the impacts from future uncertainties of a changing climate.

WSWS 2019 STUDENT PAPER AND POSTER AWARDS

The 2019 WSWS Student Paper and Poster Contest had 54 contestants: 8 undergraduate students submitted poster presentations, 22 graduate students submitted posters, and 24 graduate students gave oral presentations. Twenty-four judges volunteered their time. The level of quality among all contestants was exceptional and participants are to be commended. In accord with WSWS operating procedures, the number of winning places in different sections varied depending on the number of students that participated in each section.

Eight students competed in the Undergraduate Poster Contest. The 1^{st} place winner was Samantha R. Nobes, University of Wyoming, "*Herbicide and Grazing Impacts on Floral Resources and Pollinator Communities*". The 2^{nd} place winner was Lauren B. Stanko, Utah State University, "*Invasive Mustard Management in Utah*".

Undergraduate Poster Winners

Samantha R. Nobes, University of Wyoming and **Lauren B. Stanko**, Utah State University

The Graduate Poster Contest was made up of 22 students and was divided into four sections.

Weeds of Agronomic Crops:

1^{st} – Lucas Kopecky Bobadilla, Oregon State University, "*The Recent Scenario of Italian Ryegrass Herbicide Resistant Frequency & Ploidy Diversity in Western Oregon*".

2^{nd} – Elizabeth G. Mosqueda, University of Wyoming, "*Economics of Cultural, Mechanical, and Chemical Weed Control Practices for Herbicide-Resistant Weed Management*".

3^{rd} – Justin Childers, Oklahoma State University, "*Non-Tolerant Wheat Response to simulated Drift of Quizalofop-P-Ethyl in Central Oklahoma*".

Weeds of Range and Forest:

1st – Shannon L. Clark, Colorado State University, "*Rimsulfuron, Imazapic, and Indaziflam Interception and Sorption by Downy Brome Thatch*".

2nd - Rachel H. Seedorf, Colorado State University, "*Effect of Indaziflam on Native Species in Natural Areas and Rangeland*".

Weeds of Horticulture Crops:

1st – Larissa Larroca de Sousa, Oregon State University, "*Comparing Herbicide Efficacy for Sucker Control in Hazelnuts*".

Basic Biology and Ecology:

1st – Abigail Barker, Colorado State University, "*Fate of Glyphosate During Production and Processing of Glyphosate-Resistant Sugar Beet*".

Poster Winners

Elizabeth Mosqueda, University of Wyoming, **Rachel Seedorf**, Colorado State University, **Abigail Barker**, Colorado State University, **Shannon Clark**, Colorado State University, **Lucas Bobadilla**, Oregon State University, and **Justin Childers**, Oklahoma State University. Not pictured, **Larissa Larroca de Sousa**, Oregon State University

Students in the oral contest also were divided into four sections with 24 entries.

Weeds of Agronomic Crops:

1st – Katie E. Driver, University of California-Davis, "*Weed Emergence Timing In California Rice*".

2nd – Clint W. Beiermann, University of Nebraska-Lincoln, "*Evaluation of Microrate POST Programs in Dry Edible Bean*".

3rd – Jodie A. Crose, Oklahoma State University, "*Confirmation and Management of ALS Resistant Horseweed (Conyza canadensis L.) in Oklahoma Winter Wheat*".

Weeds of Agronomic Crops

Clint Beiermann, University of Nebraska-Lincoln, **Katie Driver**, University of California-Davis, and **Jodie Crose**, Oklahoma State University

Range, Forest, and Natural Areas:

1st – Christie Hubbard Guetling, University of Idaho, "*Plant Distribution Data Aid Creation of Invasion Susceptibility Models in the Greater Yellowstone Ecosystem*".

Weeds of Horticulture Crops:

1st – Eric Augerson, Oregon State University, *"Evaluation of Thermal, Mechanical, and Chemical Weed Control in Organic Northern Highbush Blueberries in Oregon*".

Range, Forest, and Natural Areas

Christie Hubbard Guetling, University of Idaho

Weeds of Horticulture Crops

Eric Augerson, Oregon State Univeristy

Basic Biology and Ecology:

1st – Hudson K. Takano, Colorado State University, "*Physiological Basis for the Contact Activity of Glufosinate*".

2nd – Elizabeth G. Mosqueda, University of Wyoming, "*Efficacy of Cultural, Mechanical, and Chemcial Weed Control for Proactive Herbicide Resistant Weed Management*".

Basic Biology and Ecology

Elizabeth Mosqueda, University of Wyoming and **Hudson Takano**, Colorado State University

Finally, a huge thank you to all the judges who contributed their time and energy for this year's contests.

WSWS 2019 ANNUAL MEETING NECROLOGY REPORT

At the Thursday breakfast business meeting, the biographies of WSWS members who passed away this year were read, and a moment of silence was observed. Those members were:

Dr. John Ray Abernathy, 73, of Lubbock passed away Tuesday, September 18, 2018. He was born January 4, 1945 to the late George Raymond and Tommy Loys (Fewell) Abernathy in Altus, Oklahoma. John graduated from Altus High School in 1963. He married Cynthia Sue (Canady) Abernathy May 24, 1969 in Tulsa, Oklahoma.

John had a passion for agriculture, graduating from Oklahoma State University in 1969, where he received his Bachelor of Science and his Master of Science in Agronomy. He continued to further his education at the University of Illinois receiving his Ph.D. in Agronomy in 1972. John held several positions over the years, he worked at Texas A&M Agricultural Experiment Station in Lubbock as a Weed Scientist and as the Resident Director for a total of 24 years. He was an International Consultant of Weed Science and Research from 1985 - 2017 and was a board member for the National Farm Life Insurance Company from 1998 - 2017. He received many awards along the way including the Outstanding Young Weed Scientist Award from the Southern Weed Science Society in 1980 and the USDA Group Award for excellence as a member of the AG-CARES team. John was named Fellow in the Weed Science Society of America and accepted the Gerald W. Thomas Outstanding Agriculturist Award from Tech's Ag College. He received the West TX Ag Chemicals Institute Award for outstanding Contributions in 1994. He retired as the Dean of the Texas Tech University College of Agricultural Sciences and Natural Resources in 2003.

Those left to cherish his memory are his wife of 49 years, Cindy; daughters, Larisa Abernathy Weldon of Keller, Christy Diann Liles and husband Larry of Frisco; siblings, Larry and wife Lynn Abernathy of Vernon, Frances Abernathy and husband Craig Sterling of San Angelo; five grandchildren, Grayson, Peyton and Megan Weldon, Abigail and Alexis Liles.

A Celebration of Life service will be held at 11:00 a.m. Saturday, September 22, 2018 at Combest Family Memorial Chapel with burial to follow at Resthaven Memorial Park.

Arnold Appleby was born on Oct. 24, 1935, raised on a farm near Formoso, KS, and died on December 6, 2018 at age 83 in Corvallis, Oregon. He received the B.S. in Agricultural Education in 1957 and M.S. in Agronomy in 1958 from Kansas State University. After teaching math and biology at Bazine High School in Kansas, he joined the faculty in Farm Crops at Oregon State University in 1959. He received the Ph.D. in Weed Science at OSU in 1962 and spent two seasons at the Pendleton Branch Experiment Station conducting weed research. He then returned to Corvallis where he was associate project leader under W.R. Furtick. In 1969, the project was divided and Furtick headed up the international work while Appleby became project leader of the domestic research. He began teaching the beginning weed control course and herbicide science course in 1965 and continued until his retirement in 1992, plus three more years post-retirement. This involved nearly 2,000 students over the 30 years.

Appleby was active in both the Weed Science Society of America and the Western Society of Weed Science. He served two terms as WSSA Secretary and was elected Vice-President in 1974. He was forced to resign because of serious experimental eye surgery, from which he eventually recovered. He was named the Outstanding Teacher in 1971, Fellow in 1976, and Outstanding Researcher in 1983.

In WSWS, he was elected to the offices from Secretary through Past President. He was named Fellow in 1976 and Outstanding Weed Scientist in 1991. He also was named Fellow in the American Society of Agronomy and the Crop Science Society of America. He served as Associate Editor for both Weed Science and Agronomy Journal.

On campus, he was named Teacher of the Year in Crop Science three times, received the R.M. Wade Award as Outstanding Teacher in the College of Agriculture, won three Distinguished Professor awards, and won several Distinguished Service awards from commodity groups and other organizations.

One part of his professional activities that he looked back with most pleasure was advising graduate students. He directed 44 M.S. programs and 30 PhD programs. He maintained an e-mail address list with about 140 ex-OSU weed personnel, with whom he maintained correspondence until his death.

He authored several books, including the history of WSWS, WSSA, the OSU Crop Science Department, the OSU weed program, and the Agricultural Research Foundation.

Following retirement, he maintained an office in Crop Science and served as Building Manager. He was on the Board of Directors of the Agricultural Research Foundation and chaired the Competitive Grant Committee of that organization for sixteen years. He was named Volunteer of the Year by the OSU Retirees Assoc. In 2001, he received the Distinguished Service award from Kansas State University. In 2009 he was named Diamond Pioneer at OSU, and in 2010, he was inducted into the OSU College of Agriculture Hall of Fame, the first on-campus faculty to be inducted in the 30-year history of the Hall.

Weed science was Appleby’s life and he always held the hope that any impact of his on that profession was beneficial.

He is survived by his wife, Gerry, of Corvallis; two sons, Brian and Brent; two sisters and a brother; five grandchildren, and five great-grandchildren.

Dr. John Clyde "J.C." Banks, of Creede, Colorado, passed away peacefully at age 72 on December 27, 2018, in Colorado Springs, Colorado surrounded by family. J.C. was born on March 22, 1946, in Cordell, OK to the late Alice Louise Pyron Banks and the late William Kenneth Banks. He grew up on a farm Southwest of Dill City, Oklahoma.

After High School, J.C. attended Cameron University, where he met the love of his life, Ruth Renee' Dowlen. They married on June 3, 1967. To this union, two children were born; son Kenneth Edward, and daughter Diana Renee'.

J.C. earned a Ph.D. in Agronomy from Oklahoma State University in 1974. Upon graduation, he began working for Eli Lilly & Co. He served as a Senior Scientist for Plant Science Field Research in Lubbock, Texas. Several years later, he was named manager of the Texas Research Station in Mission, Texas, overseeing the management and operation of Lilly's Plant Science Research Center in the Rio Grande Valley. In the early 1980s, J.C. was named Regional Research Representative for the Southwest Region based in Dallas, Texas. He was responsible for the EPA Experimental Permit Program, product development, and technical service for the Texas, Oklahoma, New Mexico, and Colorado region. In 1987 he was transferred to Greenfield, Indiana where he covered the North Central Region.

With a desire to get back to his roots, he resigned from Eli Lilly & Co in 1988 and returned to Oklahoma to serve as the Director of the OSU SW Research and Extension office in Altus, OK as well as the OSU Extension Cotton Specialist. In 1995 Ag Consultant Magazine named J.C. "Consultant of the Year". He was also honored at the Beltwide Cotton Conference in 1998 as "Cotton Specialist of the Year". He had a special connection with many of the farmers in the region and considered them friends.

J.C. was a talented craftsman and enjoyed woodworking, blacksmithing, and working with metal. He had a well-earned reputation for being able to fix just about anything. He greatly enjoyed his church family and friends in Creede and was always happy to help people in the community.

J.C. is survived by his wife, Renee'; his children Kenny Banks (Shannon) and Diana Collier (Robbie); Four grandchildren: Kyndal Beasley (Matthew), Paige Banks, Tristan Collier, and Ethan Collier; and one great-grandson, Owen Beasley; his sister, Naea (Les) Teachman, and brother Bill (Pam) Banks. He was the best father, husband, son, brother, and "Grampy". He will be missed dearly by all of his family and friends.

A service of remembrance will be held at Creede Baptist Church on February 16, 2019, at 10:00 am. In lieu of flowers, please consider a donation in his memory to Creede Baptist Church – 600 La Garita St – Creede, CO 81130.

Timothy Chicoine, 61, of St. Marys, Iowa died unexpectedly in a kayaking accident January 5, 2019. An avid sportsman and experienced kayaker, he died doing what he loved surrounded by some of his finest friends.

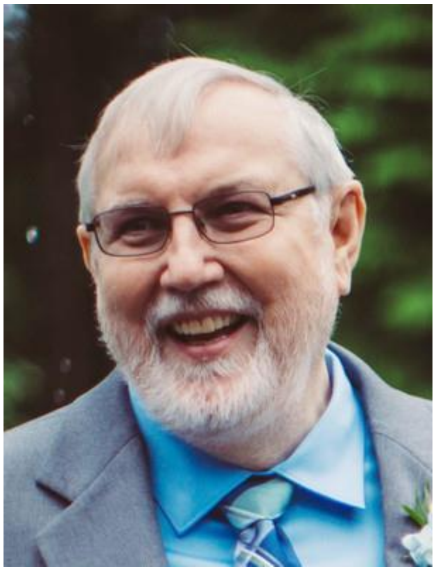
Born December 31, 1957 to the late Roland & Evelyn Chicoine, he was the 5th of 8 children. Growing up on the family farm in Elk Point, South Dakota taught Tim the values of hard work, integrity, family life, and faith. After high school, he attended South Dakota State University and Montana State University. At MSU, he met the future love of his life, Shannon, with whom he would spend 30 happy years and be blessed with 3 children. He crisscrossed the globe during his nearly 30 years of service to DuPont as an agronomist, ensuring more people could benefit from healthy, abundant food sources. His passion was the outdoors: whether camping with the family, in a boat with his friends, or spending time pruning the fruit trees on the family acreage, he was a man of nature. He deeply loved his family and friends and always had a smile for anyone he met. He was active in his local community and served the last 3 years as Grand Knight for the St Marys Knights of Columbus.

Tim was preceded in death by his parents Roland & Evelyn Chicoine, his mother-in-law Beverly Martin, and nephew Jason Chicoine. He is survived by his wife, Shannon, children: The Rev. Trevor Chicoine of West Des Moines, Kaley Chicoine of Eugene, Oregon, and Naomi Chicoine of Ames, siblings Jeff (Chris), David (Marcia), Marcia (Pat) Quinn, Danny (Penny), Brian (Terri), Nicole (Joe) Klein, Ellen (Bryan) Little and a host of nieces, nephews, and cousins.

Visitation will be Friday, January 11 from 4:00 PM to 7:00 PM, at Immaculate Conception Church in St. Marys, Iowa. Funeral Services, with his son presiding, will be Saturday, January 12 at 10:30 AM at St. Thomas Aquinas Catholic Church in Indianola, Iowa, with internment in St. Marys parochial cemetery to follow. Memorials may be directed to the Diocese of Des Moines seminarian fund or the Iowa Rivers Revival.

Nelroy Evan Jackson, Ph.D. passed away in Corona, California on Sunday July 29, 2018. Nelroy was passionate about controlling invasive weed species and was instrumental in the development of herbicides for vegetation control in the west during his tenure at Monsanto. He was a founding board member of the California Exotic Pest Plant Council and served on the National Invasive Species Advisory Committee. Nelroy was awarded Fellow of the Western Society of Weed Science in 2005. He also received the Presidential Award of Merit and the Outstanding Industry Award from Weed Science Society of America.

He is survived by his wife; Barbara, sons and daughters in law; Stephen, Evan, Kimberly, and Maria, and grandchildren; Cyan, Mia, and Noelle, as well as numerous other family members. A memorial service in celebration of Nelroy's life was held in Corona on August 3, 2018.



Michael Vernon Hickman died in Seattle, Washington on May 26, 2018 while seeking treatment for a rare blood cancer, Chronic Myelomonocytic Leukemia (CMML). He was born in Galion, Crawford County, Ohio to Frank Daniel and Eva Maude Longacre Hickman on January 5, 1951. He graduated from Cardington High School in Cardington, Ohio, and attended Ohio State University at Marion and Washington State University for his undergraduate degrees. He earned a M.S. in Agronomy at Washington State University and a Ph.D. in Agronomy at North Dakota State University in 1988.

He served as a nuclear engine machinist mate in the U.S. Navy from 1972-1977 aboard the submarine, the U.S.S. Nathan Hale. He married Nancy A. Greenwood in Fargo, North Dakota on August 9, 1986 and they lived in Fargo, North Dakota; Overland Park, Kansas; Weslaco, Texas; and resided in Lafayette, Indiana for the past 28 years. Dr. Hickman worked as a Weed Scientist for the U.S. Department of Agriculture at Weslaco, Texas and in West Lafayette at Purdue University, and more recently as a high school science teacher at Central Catholic High School and McCutcheon High School teaching physics, chemistry, and A.P. Biology. Nothing was more important to Doc than helping each student become the best he or she could be.

Mike was loved by his colleagues and students alike for his enthusiasm for science, sarcastic wit, sense of humor, Hawaiian shirts, and especially his smile. He enjoyed reading science but also loved reading about WWII, submarines, and science fiction. He shared a love for learning about his family history with his wife, digging through archives and tramping through cemeteries. Mike also enjoyed volunteering for a local cat rescue and at other community events. But above all he enjoyed time spent with his wife and daughter: cooking, laughing, and enjoying each other's company.

In addition to his wife, Mike is survived by his daughter, Mikael Anne Greenwood-Hickman and son-in-law, Ryne Torri of Seattle, Washington; brothers Daniel (wife Judy) Hickman of Coats, North Carolina; William Hickman of Fulton, Ohio, and Jon Hickman (wife Kim) of Perry, Georgia; sisters Sarah Ott of Sahuarita, Arizona; Cathy Smothers (husband Steve Lane) of Columbus, Ohio; and sister-in-law, Terri Cox Hickman of Fulton, Ohio; as well as many nieces and nephews all of whom he loved very much. He was predeceased by his parents; his brother, Kenneth Hickman; and a nephew, Greggory Hickman.

Rupert DeWitt Palmer of Bryan passed away January 14, 2019. Rupert was born at home January 28, 1929 in Winston County Mississippi to James Thomas Palmer and Coley Ree (Miles) Palmer. He holds an AA in Agriculture from East Central Junior College 1949, a BS in agricultural administration 1952, and a MS in Agronomy 1954 from Mississippi State University and a Ph.D. in Botany from Louisiana State University 1959.

He met and was married to Reida Wilkie White August 22, 1954. They had a candlelight ceremony at Ethel Baptist Church. They walked the pathway of life hand in hand for 62 years.

Rupert was stationed in the US Army Medical Corps at Fort Chaffee, Arkansas. His name is listed on the Wall of Honor in Veterans Park, College Station, Texas.

He was employed in 1959 to 1966 by Mississippi State University as a Plant Physiologist in the Mississippi Agricultural Experiment Station. He taught undergraduate and graduate courses as Associate Professor of Agronomy (Weed Science). He was major professor for graduate students in weed science. He was awarded the FAA State Farmer in Mississippi for his teaching vocational agricultural teachers weed control methods and weed identification.

He was an Extension Weed Specialist from 1966 to his retirement in 1989 with the Texas Agricultural Extension Service, Department of Soil and Crop Sciences, Texas A&M University. He enrolled in rangeland resource management at Texas A&M, and other staff short courses. He was elected to Gamma Sigma Delta, the honor society of agriculture. At his retirement January 31, 1989 the plaque contained the message "In honor of his untiring effort in identifying and recoding weeds of Texas and his service to Texas Agriculture".

Rupert was an avid golfer who shot his age a number of times, was active in the Men's golf association, and applied his background to improving the condition of then Briarcrest Country Club.

Rupert was preceded in death by his parents; his wife Reida; his brothers Haron and Joel; and his sisters Frances R. Humphries and Merry Z. Rainey. He is survived by his son Robert T. Palmer and wife Lorraine; his daughter Regina P. Wheaton and husband William; his grandchildren, Alexander W. Wheaton, Alison R Wheaton, Ramsey E. Palmer, Robert T. Palmer, Jr., and Reanna E. Palmer; his brothers, James O. Palmer and Pettus T. Palmer; and numerous nieces and nephews.

William Maurice (Bill) Phillips died December 2, 2018 at the age of 95. He was born December 4, 1922 at Newton, Kansas, the youngest of five children of S. Clayton and Minnie (Vesper) Phillips. He was preceded in death by his parents, three brothers and one sister, infant son Stanley Glenn and daughter Carol Jean Frye. Survivors include his wife Doris of the home, children Bob and Roya Phillips, Fullerton, California, Don and Becky Phillips, Alexandria, Virginia, Roger and Sue Phillips, Rio Rancho, New Mexico, seven grandchildren and four great grandchildren.

Both Bill and Doris were involved in many of their children's activities including Boy Scouts, Girl Scouts, 4-H, and church activities. Bill grew up on farms in Harvey County, Kansas. His primary schooling was in a one room rural school where he was often the only student in his grade. Beginning with the ninth grade he attended Newton High School where he graduated in 1940. He enrolled in Kansas State College (now University) in the fall of 1940. After completing two years of college he enlisted in the United States Army Air Forces in November 1942.

Following basic training he was assigned to Bombsight and Automatic Pilot Training School located at Lowry Field, Denver, Colorado. After completing the course, he became part of the original cadre of the 745th Bomb Squadron, 456th Bomb Group, 15th Army Air Forces. Most of the state-side training was at Muroc, California (near the site of the present Edwards Air Force Base). Late in 1943 the unit, which flew B-24 bombers, was sent to Italy. The squadron remained on the same field, located near Cerignola, until July 5, 1945. Bombing missions were flown to various targets in southern Europe and Germany. As a member of the ground crew, Bill was not involved in combat missions. He was in charge of bombsight and automatic pilot service and maintenance on the squadron's B-24 bombers. He reached the rank of Technical Sergeant and was awarded the Bronze Star medal. He returned to the U.S. in August 1945 and was honorably discharged.

After spending a short time with his parents in Harvey County Kansas, he returned to Manhattan to look for employment. (All classes at the University had already started.) When applying for a job at the Kansas Crop Improvement Association he met Doris Mead, Office Manager for the Association. He and Doris were married April 18, 1946. Following a few months' work, Bill enrolled at the University for the 1946 spring semester. He received his Bachelor of Science degree in 1947, enrolled in Graduate School and received his Master of Science degree in 1949. On February 1, 1948 he began working for the Agricultural Research Service, U.S. Department of Agriculture. He was located at the Fort Hays Branch, Kansas Agricultural Experiment Station, Kansas State University, Hays, Kansas, as a cooperative State-Federal employee doing research on methods of controlling weeds in field crops. This began a long career in weed control research that, except for a 10-month assignment on a brush control project at Spur, Texas, was spent at the experiment station at Hays. Because of a reduction in force of federal employees, Bill left federal service in 1973 and was employed by Kansas State University. His research was only slightly affected by this change.

In July 1976 he became Head of the Fort Hays Experiment Station and remained in that position until he retired in January 1985 with the academic rank of professor. During his career and following his retirement, Bill was recognized and honored for several achievements in weed control research and for developing improved farming practices using those research findings. His pioneering work in conservation tillage practices and weed control strategies in a winter wheat-grain sorghum-fallow cropping system for the Great Plains led to wide-spread acceptance of this farming system. This and other research were documented by many technical and popular publications and presentations. He was a member or past member of several professional and honorary scientific organizations including the Weed Science Society of America, North Central Weed Science Society, American Society of Agronomy, Council for Agricultural Science and Technology, Sigma Xi, Gamma Sigma Delta, and Alpha Zeta.

In 2001 he wrote the 100-year history of the Agricultural Research Center-Hays (formerly called the Fort Hays Experiment Station). The history, published by Kansas State University, was presented as part of the Center's Centennial Celebration. When Bill retired in January 1985 he and Doris moved to Manhattan where they enjoyed university, church, and community activities. They traveled extensively, both to visit family and to tour other parts of the world. They celebrated their 72nd wedding anniversary April 18, 2018. Both Bill and Doris were active in the Presbyterian Church. Bill was a ruling elder for many years in the church in Hays and served as Trustee, church treasurer, and on many church committees.

WSWS 2019 ANNUAL MEETING RETIREES REPORT

Since the last meeting, a total of four members of the society were brought forward as new or soon to be retired from the Western Society of Weed Science. The first three members were in attendance of our Denver meeting, and thus were formally recognized at the Awards Luncheon. All four members spent all or nearly all of their careers in the Pacific Northwest. Their attendance, years of service, and professional leadership will be greatly missed.

Don Morishita grew up in southeastern Idaho and received his B.S. at Utah State, M.S. and Ph.D. at University of Idaho. Don started his career at Kansas State University, Garden City, Kansas and then moved back to Idaho, as the Extension Specialist/Professor of Weed Science, and more recently Superintendent of the Kimberly Research and Extension Center.

WSWS: Research Section Chair, Education and Regulatory Section Chair, Secretary, President, and Fellow. Also 2019 Outstanding Weed Scientist.

Carol Mallory-Smith grew up in southeastern Washington and received her B.S. and Ph.D. at University of Idaho. As a teacher and researcher at Oregon State University, Carol became Professor of Weed Science.

WSWS: Research Section Chair, Member at Large, Outstanding Weed Scientist, Presidential Award of Merit, and Fellow. Also WSSA President and WSSA Fellow.

Tim Miller grew up in southwestern Idaho, and received his B.S., M.S., and Ph.D. at the University of Idaho. Tim conducted extension work with University of Idaho before working for Washington State University at the Mount Vernon Research and Extension Center as Extension Weed Scientist.

WSWS: Ed and Reg Section Chair, WSSA rep, WSWS rep for Constitution and Operating Procedures, Presidential Award of Merit (twice), and Fellow.

Don Drader grew up in southeastern Washington and received his degree in Agronomy from Washington State University. Don began his agricultural career in Moses Lake with a small family owned processor as a field man before starting with Stauffer Chemical. He retired as an Agronomist after more than 38 years with Syngenta and legacy companies, all served in the PNW.

Submitted by Monte Anderson, Immediate Past President

WSWS 2019 ANNUAL MEETING ATTENDEES – Denver, Colorado

Albert Adjesiwor
University of Wyoming
Dept 3354
1000E University Avenue
Laramie, WY 82071
aadjesiw@uwyo.edu

Joshua Adkins
Rohlfs and Adkins Research
4562 Barbera ST
Richland, WA 99352
joshua.ira.adkins@gmail.com

Kassim Al-Khatib
Univeristy of California
279A Robbins Hall-MS-4
One Shields Ave.
Davis, CA 95616
kalkhatib@ucdavis.edu

Clarke Alder
The Amalgamated Sugar Company
138 West Karcher Rd
Nampa, ID 83687
calder@amalsugar.com

Craig Alford
Corteva Agriscience
6900 NW 62nd Ave
Johnston, IA 50131
craig.alford@dupont.com

Jill Alms
South Dakota State University
235 Ag Hall
Brookings, SD 57007
jill.alms@sdstate.edu

Aman Anand Anand
1986
1290 Fifield Place
Falcon Heights, MN 55108
amanrajbhu@gmail.com

Monte Anderson
Bayer Cropscience
16304 South Yancey Lane
Spangle, WA 99031-9563
monte.anderson@bayer.com

Alyssa Armbruster
City of Fort Collins Natural Areas
1745 Hoffman Mill Road
Fort Collins, CO 80521
aarmbruster@fcgov.com

Raul Arroyo Rosas
Washington State University
Crop and Soil Science
Pullman, WA 99164-6420
raul.arroyo96@wsu.edu

Mike Auciello
City of Fort Collins Natural Areas
1745 Hoffman Mill Rd
Fort Collins, CO 80524
mauciello@fcgov.com

Mike Auciello
Larimer County Natural Resources
2649 E. Mulberry, Suite 6
Fort Collins, CO 80522
aucielmi@co.larimer.co.us

Erik Augerson
Oregon State University
2750 SW Campus Way
Corvallis, OR 97331
augersoe@oregonstate.edu

Dirk Baker
Campbell Scientific, Inc.
815 West 1800 North
Logan, UT 84321
dbaker@campbellsci.com

Joe Ballenger
605 S. 30th st, Apt. 5101-A
Laramie, WY 82070
joeballenger2005@gmail.com

Phil Banks
Marathon Ag Consutlting
205 W Boutz BLDG 4 STE 5
Las Cruces, NM 88005
marathonag@zianet.com

Nicholas Bankston
Fremont County Weed Management
201 N 6th St, Rm 118
Canon City, CO 81212
nick.bankston@fremontco.com

Abigail Barker
Colorado State University
1177 Campus Delivery
Fort Collins, CO 80523
barkeral@rams.colostate.edu

Judit Barroso
Oregon State University
48037 Tubbs Ranch Road
Adams, OR 97810
judit.barroso@oregonstate.edu

Matt Baur
Western IPM Center
2801 Second St
Davis, CA 95618-7774
mebaur@ucanr.edu

Travis Bean
University of California, Riverside
Riverside, CA 92507
travis.bean@ucr.edu

George Beck
Alligare, LLC
6780 Rodney St
Windsor, CO 80550
George.Beck@Alligare.com

Cody Beckley
Utah State University
4820 Old Main Hill
Logan, UT 84341
cody.beckley@usu.edu

Lesley Beckworth
Teton County Weed & Pest
7575 S Highway 89
Jackson, WY 83001
lbeckworth@tcweed.org

Clint Beiermann
University of Nebraska Lincoln
4502 Ave I
Scottsbluff, NE 69361
clint.beiermann@huskers.unl.edu

Carol Bell-Randall
US Forest Service
PO Box 159 173 Commerce Drive
Smelterville, ID 83868-0159
crandall@fs.fed.us

Steve Bergsten
AgraServ, LLC
2565 Freedom Lane
American Falls, ID 83211
steve@agraserv.com

Jared Beuschlein
Washington State University
1100 NE Stadium Way Apt 24
Pullman, WA 99163
jared.beuschlein@wsu.edu

Tina Booton
Weld County Public Works
PO Box 758
Greeley, CO 80632
tbooton@weldgov.com

Raven Bough
Colorado State University
200 W Lake St
Fort Collins, CO 80523
raven.bough@colostate.edu

Brianna Brannan
Rio Grande County Weed District
1064 W County Rd
Monte Vista, CO 81144
rgweed@riograndecounty.org

Matthew Brooke
North Dakota State University
PO Box 6050
Fargo, ND 58108-6050
matthew.brooke@ndus.edu

Donald Brooks
Colorado State University
1201 West Plum St, Apt 222
Fort Collins, CO 80521
donald.brooks@colostate.edu

Robert Bruss
Nufarm Americas, Inc.
4020 Aerial Center Parkway
Morrisville, NC 27560
bob.bruss@nufarm.com

Hailey Buell
Utah State University
Champ Dr
Logan, UT 84322
hailey.lynn.buell@aggiemail.usu.edu

Marvin Butler
Oregon State University-COARC
850 NW Dogwood Lane
Madras, OR 97741
marvin.butler@oregonstate.edu

Joan Campbell
University of Idaho
875 Perimeter Drive MS 2333
Moscow, ID 83844-2333
jcampbel@uidaho.edu

James Carey
Hubbard Ag Science
85 Tuttle ln
Burbank, WA 99323
james@hubbardagscience.com

Ken Carlson
FMC Agricultural Solutions
16560 S. Marais Drive
Olathe, KS 66062
kenneth.carlson@fmc.com

John Chapman
Julius Ag Inc
2073 45 1/2 Rd
De Beque, CO 81630
johnchap5@gmail.com

Justin Childers
Oklahoma State University
371 Ag Hall
Stillwater, OK 74078
just.tanner.childers@okstate.edu

Shannon Clark
Colorado State University
380 Aurora Way
Fort Collins, CO 80525
shannon.clark@colostate.edu

Pat Clay
Valent U.S.A. LLC
7498 N. Remmington Ave., Ste 102
Fresno, CA 93711
Pat.Clay@valent.com

David Claypool
University of Wyoming
Dept 3354 1000 E University Ave
Laramie, WY 82071
claypool@uwyo.edu

Bill Cobb
Cobb Consulting Services
815 South Kellogg
Kennewick, WA 99336
wtcobb42@gmail.com

Carl Coburn
9751 S E State Farm Rd
Maxwell, NE 69151
carl.coburn@bayer.com

Scott Cook
Hubbard Ag Sciences
1915 N. Ivory Ln
Post Falls, ID 83854
scott@hubbardagscience.com

Jacob Courkamp
Colorado State University
1472 Campus Delivery
Fort Collins, CO 80523-1472
jacob.courkamp@colostate.edu

John Coyle
Ark Valley Weed Mgmt &
Consulting, LLC
515 Greenwood Ave
Canon City, CO 81212
avweeds@gmail.com

Cody Creech
University of Nebraska
4502 Ave I
Scottsbluff, NE 69361
ccreech2@unl.edu

Jodie Crose
Oklahoma State University
371 Ag Hall
Stillwater, OK 74078
jodie.crose@okstate.edu

Randy Currie
KSU Southwest Res & Ext
4500 E Mary Street
Garden City, KS 67846-9132
rscurrie@ksu.edu

Dan Curtis
Oregon State University
107 Crop Science Bldg
Corvallis, OR 97331
Daniel.Curtis@oregonstate.edu

Greg Dahl
Winfield United
3336 Casey Street
River Falls, WI 54022
gkdahl@landolakes.com

Caleb Dalley
PO Box 1377
Hettinger, ND 58639
caleb.dalley@ndsu.edu

Edward Davis
Montana State University
334 Johnson Hall
Boxeman, MT 59717-3120
edavis@montana.edu

Caio De Castro Grossi Brunharo
Oregon State University
Crop Science Building 331B
Corvallis, OR 97330
caio.brunharo@oregonstate.edu

James Dollins
U.S. Forest Service
3625 93rd Ave SW
Olympia, WA 98512
jdollins@fs.fed.us

Andrew Donaldson
Oregon State University
2750 SW Campus Way
Corvallis, OR 97333
donaldsa@oregonstate.edu

Chad Effertz
UPL
4551 HWY 41N
Velva, ND 58790
chad.effertz@arysta.com

Greg Endres
North Dakota State Unversity
Res Ext Center BOX 219
Carrington, ND 58421-0219
gregory.endres@ndsu.edu

Jeanne Falk Jones
Kansas State University
PO Box 786
Colby, KS 67701
jfalkjones@ksu.edu

Joel Felix
Oregon State University
595 Onion Avenue
Ontario, OR 97914
joel.felix@oregonstate.edu

Marcelo Figueiredo
Colorado State University
1179 Campus Delivery
Fort Collins, CO 80523
mrafig@colostate.edu

Andrew Fillmore
West Central Distribution
153 Covey Court Unit D
Bozeman, MT 59718
afillmore@wcdst.com

Bob Finley
Fremont County Weed & Pest
PO BOX 1171
Dubois, WY 82513
rfinley@dteworld.com

Taylor Fletcher
City of Northglenn
11701 Community Drive
Northglenn, CO 80233
tfletcher@northglenn.org

Pete Forster
Syngenta Crop Protection
35492 WCR 43
Eaton, CO 80615-9205
pete.forster@syngenta.com

Beth Fowers
University of Wyoming
3401 Coffeen Ave
Sheridan, WY 82801
bfowers@uwyo.edu

John Frihauf
BASF Corporation
2401 Pester Ridge Rd
Lincoln, NE 68523
john.frihauf@basf.com

Aaron Froemke
North Dakota State University
13969 65th SE
Lisbon, ND 58054
aaron.m.froemke@ndsu.edu

Angela Gadino
UPL NA
864 Sage Crest Dr.
Wenatchee, WA 98801
angela.gadino@uniphos.com

Todd Gaines
Colorado State University
1177 Campus Delivery
Fort Collins, CO 80523
todd.gaines@colostate.edu

Mariano Galla
ISK Biosciences
229 E 242nd Street
Euclid, OH 44123
gallam@iskbc.com

Roger Gast
Dow AgroSciences
9330 Zionsville RD
Indianapolis, IN 46268
regast@dow.com

Charles Geddes
AAFC
5403 1st Ave S
Lethbridge, Alberta T1J 4B1
Charles.Geddes@canada.ca

Thomas Getts
UCCE
707 Nevada st.
Susanville, CA 96130
tjgetts@ucanr.edu

Derrick Gonzales
City of Lakewood
2775 S Estes St
Lakewood, CO 80227
dergon@lakewood.org

Brian Goyette
City of Lakewood
2775 S Estes St
Lakewood, CO 80227
brigoy@lakewood.org

Greta Gramig
North Dakota State University
P.O. Box 6050 Dept. 7670
Fargo, ND 58108-6050
greta.gramig@ndsu.edu

James Gray
2,4-D Research Task Force
9317 E Pleasant Ave
Kansas City, MO 64138
james.gray@24d.org

Gino Graziano
3600 Denali Street
Anchorage, AK 99503
gagraziano@alaska.edu

Matthew Gregoire
Vision Research Park
317 1st Avenue SE
Berthold, ND 58718
matt@visionresearchpark.com

Daniel Guimaraes Abe
North Dakota State University
102 US-12 Hwy
Hettinger, ND 58639
daniel.abe@ndsu.edu

Alan Haack
Belchim Crop Protection, USA LLC
1571 Misty Wood DR
Roseville, CA 95747
alan.haack@comcast.net

Ryan Hageman
West Central
208 Airport Drive S
Lake Preston, SD 57249
rhageman@wcdst.com

Mustapha Haidar
Amerian University of Beirut
Bliss ST, AUB, FAFS
Beirut, NY 10017-2303
mhaidar@aub.edu.lb

Brad Hanons
University of California - Davis
Dept. of Plant Sience MS-4;
Davis, CA 95616
bhanson@ucdavis.edu

Timothy Harrington
USDA Forest Service
3625 93RD AVE SW
Olympia, WA 98512
tharrington@fs.fed.us

Marshall Hart
University of Wyoming
3401 Coffeen Ave
Sheridan, WY 82801
mhart12@uwyo.edu

Charles Hart
Dow AgroSciences
920 Bell Plains Rd
Abilene, TX 79606
crhart@dow.com

Audrey Harvey
Montana State University
PO BOX 173120
Bozeman, MT 59718
audrey.harvey@student.montana.edu

William Hatler
Corteva Agriscience
3022 S. Bailey Way
Meridian, ID 83642
william.l.hatler@dupont.com

Harlene Hatterman-Valenti
North Dakota State University
PO Box 6050, Dept 7670
Fargo, ND 58108-6050
h.hatterman.valenti@ndsu.edu

Brennan Hauk
National Park Service
231 E St Joseph St
Rapid City, SD 57701
brennan_hauk@nps.gov

Alan Helm
Gowan Company
13450 Success Rd
Success, MO 65570
ahelm@gowanco.com

Rabecka Hendricks
University of Idaho
3806 N 3600 E
Kimberly, ID 83341
rwilliamson@uidaho.edu

Guy Hernandez
California Poly - Pomona
3801 W Temple Ave
Pomona, CA 91768
gghernandez@cpp.edu

Charlie Hicks
Bayer Cropscience
3008 Shore Rd
Fort. Collins, CO 80524
charlie.hicks@bayer.com

Stott Howard
Syngenta Crop Protection
416 Foster Drive
Des Moines, IA 50312
stott.howard@syngenta.com

Kirk Howatt
North Dakota State University
PO BOX 6050
Fargo, ND 58108-6050
kirk.howatt@ndsu.edu

Christie Hubbard Guetling
University of Idaho
875 Perimeter Dr. MS2331
Moscow, ID 83844-2331
hubb5924@vandals.uidaho.edu

Andy Hulting
Oregon State University
109 Crop Science Building
Corvallis, OR 97331-3002
andrew.hulting@oregonstate.edu

Pamela Hutchinson
University of Idaho
Aberdeen R & E Center
1693 S. 2700 W.
Aberdeen, ID 83210
phutch@uidaho.edu

Joe Ikley
North Dakota State University
470H Loftsgard Hall
Fargo, ND 58108
joseph.ikley@ndsu.edu

Randa Jabbour
University of Wyoming
1000 E University Ave #3354
Laramie, WY 82071
rjabbour@uwyo.edu

James Jackson
Texas A&M AgriLife Extension
1229 U.S. Hwy 281
Stephenville, TX 76401
Jamesr.Jackson@ag.tamu.edu

Jeremy James
UCANR
67826 Scott Forbes Rd
Browns Valley, CA 95946
jjjames@ucanr.edu

Catherine Jarnevich
U.S. Geological Survey,
2150 Centre Ave Bldg C
Fort Collins, CO 80526
jarnevichc@usgs.gov

Jake Jarrett
Park County Weed and Pest
1067 Road 13
Powell, WY 82435
jake@parkcountyweeds.org

Eric Jemmett
Jemmett Consulting & Res. Farm
24996 Goodson Rd
Parma, ID 83660
ericjemmett@yahoo.com

Brian Jenks
North Dakota State University
5400 HWY 83 South
Minot, ND 58701
brian.jenks@ndsu.edu

Prashant Jha
Montanta State University
748 Railroad Highway
Huntley, MT 59037
pjha@montana.edu

Anjani Jha
Montana State University
748 Railroad Highway
Huntley, MT 59037
anjani.jha@montana.edu

Paul Johnson
South Dakota State University
Box 2207A
Brookings, SD 57007
paulo.johnson@sdstate.edu

Christopher Jones
938 W Garden Circle
Nibley, UT 84321
m.joneschris@gmail.com

Mithila Jugulam
Kansas State University
2004 Throckmorton,
Manhattan, KS 66506
mithila@ksu.edu

Kyle Keller
BASF Corporation
6315 Guess RD
Rougemont, NC 27572
kyle.keller@basf.com

Brenda Kendall
1693 S 2700 W
Aberdeen, ID 83210
brendakendall35@yahoo.com

Robert Klein
Univeristy of Nebraska
402 West State Farm Rd
North Platte, NE 69101-7751
rklein1@unl.edu

Andrew Kniss
University of Wyoming
Dept 3354 1000 E University Ave
Laramie, WY 82071
akniss@uwyo.edu

Rick Kobs
City of Lakewood
2775 S. Estes St
Lakewood, CO 80227
rickob@lakewood.org

Lucas Kopecky Bobadilla
Oregon State University
3227 NW Orchard Ave
Corvallis, OR 97330
lucas.kopecky-bobadilla@oregonstate.edu

Vipan Kumar
Kansas State University
1232 240 Ave,
Hays, KS 67601
vkumar@ksu.edu

Larissa Larocca de Souza
Oregon State Univ.
980 NE Walnut Blvd.
Corvallis, OR 97330
larissa.larocca@hotmail.com

Nevin Lawrence
University of Nebraska-Lincoln
4502 Avenue I
Scottsbluff, NE 69361
nlawrence2@unl.edu

Richard Lee
USDI, BLM
P. O. Box 25047
Denver, CO 80225-0047
r5lee@blm.gov

Erik Lehnhoff
New Mexico State University
Entom, Plant Path & Weed Science
Las Cruces, NM 88011
lehnhoff@nmsu.edu

Glenn Letendre
Syngenta Crop Protection
11852 W Oneida DR
Boise, ID 83709-3882
glenn.letendre@syngenta.com

Carl Libbey
WSWS Newsletter/Proceedings
225 S. 10th Street
Mount Vernon, WA 98274
weedcoug@gmail.com

Rui Liu
Kansas State University
1232 240th Ave
Hays, KS 67601
tabitha723@tamu.edu

Kelly Luff
Bayer Cropscience
3554 East 4000 North
Kimberly, ID 83341
kelly.luff@bayer.com

Drew Lyon
Washington State University
PO BOX 646420
Pullman, WA 99164-6420
drew.lyon@wsu.edu

John Madsen
USDA-ARS/UC-Davis
Plant Sciences, Mail Stop 4
Davis, CA 95616
jmadsen@ucdavis.edu

Michelle Majeski
Montana State University
P.O. Box 173120
Bozeman, MT 59717
michellemajeski@montana.edu

Lori MaKarick
1201 Oakridge Dr #200
Fort Collins, CO 80525
lori_makarick@mps.gov

Carol Mallory-Smith
Oregon State University
107 Crop Science Bldg
Corvallis, OR 97331
carol.mallory-smith@oregonstate.edu

Jane Mangold
Montana State University
PO BOX 173120
Bozeman, MT 59717
jane.mangold@montana.edu

Misha Manuchehri
Oklahoma State University
371 Agricultural Hall
Stillwater, OK 74078
misha.manuchehri@okstate.edu

Dean Maruska
Bayer Cropscience
408 E. Johnson Ave
Warren, MN 56762
dean.maruska@bayer.com

Chloe Mattilio
University of Wyoming
1000 East University Avenue
Laramie, WY 82070
cmattili@uwyo.edu

Christopher Mayo
Bayer Crop Science
625 Plum Creek Circle
Gardner, KS 66030
christopher.mayo@bayer.com

Bill McCloskey
University of Arizona
PO BOX 210036
Tucson, AZ 85721-0036
wmcclosk@email.arizona.edu

Sandra McDonald
Mountain West Pest
2960 Southmoor Drive
Fort Collins, CO 80525
sandrakmcdonald@gmail.com

Janis McFarland
Syngenta Crop Protection
410 Swing Road
Greensboro, NC 27409
janis.mcfarland@syngenta.com

Gary Melchior
Gowan Company
625 Abbott Rd
Walla Walla, WA 99362
gmelchior@gowanco.com

Joseph Mettler
North Dakota State University
PO Box 6050
Fargo, ND 58108
joseph.mettler@ndsu.edu

Jordan Meyer-Morey
Montana State University
100 Culbertson Hall
Bozeman, MT 59717
jordan.meyermorey@student.montana.edu

Celestina Miera
University of Idaho
1693 S 2700 W
Aberdeen, ID 83210
cmiera@uidaho.edu
Tim Miller
Washington State University
16650 SR 536
Mount Vernon, WA 98273-9761
twmiller@wsu.edu

Marcelo Moretti
Oregon State University
4017 AG Life Sciences Bldg
Corvallis, OR 97331
marcelo.moretti@oregonstate.edu

Don Morishita
University of Idah
3806 North 3600 East
Kimberly, ID 83341
don@uidaho.edu

Elizabeth Mosqueda
University of Wyoming
1000 E University Ave.
Laramie, WY 82071
emosqued@uwyo.edu

Thomas Mueller
University of Tennessee
2431 Joe Johnson Dr
Knoxville, TN 37996
tmueller@utk.edu

Todd Neel
USDA Forest Service
26 Fort Missoula Rd
Missoula, MT 59804
toddaneel@fs.fed.us

George Newberry
Gowan Company
1411 South Arcadia Street
Boise, ID 83705
gnewberry@gowanco.com

Scott Nissen
Colorado State University
115 Weed Research Lab
Fort Collins, CO 80523-1179
scott.nissen@colostate.edu

Samantha Nobes
University of Wyoming
4746 E Skyline Dr. #76
Laramie, WY 82070
snobes@uwyo.edu

Noelle Orloff
Montana State University
P.O. Box 173120
Bozeman, MT 59717
noelleorloff@montana.edu
Mirella Ortiz
Colorado State University
1179 Campus Delivery
Fort Collins, CO 80523
mirella.fortiz@gmail.com

Mike Ostlie
North Dakota State University
PO BOX 219
Carrington, ND 58421
mike.ostlie@ndsu.edu

Balaji Aravindhan Pandian
Kansas State University
Throckmorton Plant Sci. Center
Manhattan, KS 66502
aravindhan@ksu.edu

Ethan Parker
7145 58th Ave
Vero Beach, FL 32967
ethan.parker@syngenta.com

Ishita Patel
University of Saskatchewan
51 Campus Drive
Saskatoon, SK S7N5A8
ishita.patel@usask.ca

Ed Peachey
Oregon State University
Hort Dept. ALS4017
Corvallis, OR 97331
peacheye@hort.oregonstate.edu

Patti Prasifka
Corteva Agriscience
3611 12TH Street West
West Fargo, ND 58078
patti.prasifka@corteva.com

Timothy Prather
University of Idaho
875 Perimeter Drive
Moscow, ID 83844
tprather@uidaho.edu

Steve Pyle
Syngenta Crop Protection
410 Swing Road
Greensboro, NC 27455
steve.pyle@syngenta.com

Harry Quicke
1140 Shoreline Drive
Windsor, CO 80550
harry.quicke@bayer.com

Kyle Race
University of Wyoming
1000 E. University Ave
Laramie, WY 82070
krace1@uwyo.edu

Gina Ramos
USDI Bureau of Land Management
1849 C St. NW
Rm 2134 LM, WO-220
Washington, DC 20240
gramos@blm.gov

Corey Ransom
Utah State University
4820 Old Main Hill
Logan, UT 84322-4820
corey.ransom@usu.edu

Ryan Rapp
Bayer CropScience
40660 252nd St
Mitchell, SD 57301
ryan.rapp@bayer.com

Traci Rauch
University of Idaho/Plant Sci Dept
875 Perimeter Drive MS 2333
Moscow, ID 83844-2333
trauch@uidaho.edu

Hale Redding
Weston County Weed and Pest
Control District
35 Fairgrounds Road
Newcastle, WY 82701
westonp1@rtconnect.net

Chris Reeves
West Central, Inc.
PO BOX 114
Beaver City, NE 68926
creeves@westcentralinc.com

Emily Repas
University of Wyoming
1000 E University Ave
Laramie, WY 82071
erepas@uwyo.edu

Lisa Rew
Montana State University
334 Leon Johnson Hall, LRES Dept
Bozeman, MT 59717
lrew@montana.edu

Jesse Richardson
Corteva
9846 Lincoln Ave
Hesperia, CA 92345
jesse.richardson@corteva.com

Jonathan Rife
Douglas County PWOPS
P.O. Box 1390
Castle Rock, CO 80109
jrife@douglas.co.us

Andy Robinson
Loftsgard Hall 166, Dept 7670
PO BOX 6050
Fargo, ND 58108
andrew.p.robinson@ndsu.edu

Steven Roehl
Loveland Products, Inc
5640 45th Avenue SW
Willmar, MN 56201
steve.roehl@nutrien.com

Kyle Roerig
Oregon State University
109 Crop Science Building
Corvallis, OR 97331
kyle.roerig@oregonstate.edu

John Roncoroni
1715 Coloma Way
Woodland, CA 95695
jaroncoroni@ucanr.edu

Ryan Ross
United Agronomy LLC
1109 6th St E
Williston, ND 58801
ryan@unitedag.com

Steve Ryder
Colorado Dept. of Agriculture
305 Interlocken Pkwy
Broomfield, CO 80021
steve.ryder@state.co.us

Kirk Sager
FMC Corporation
5431 RD 11.7 NW
Ephrata, WA 98823
kirk.sager@fmc.com

Osama Saleh
University of Wyoming
1000 E. University Ave.
Laramie, WY 82071
osaleh@uwyo.edu

KaMele Sanchez
Colorado State University
318 West Prospect, Apt 235
Fort Collins, CO 80526-201
mele@rams.colostate.edu

Kelly Satrom
North Dakota State University
5231 Ambavalley Pwky S Apt 20
Fargo, ND 58104
kelly.t.satrom@ndsu.edu

Steve Sauer
Boulder County Parks & Open Space
5201 St. Vrain Rd
Longmont, CO 80503
ssauer@bouldercounty.org

Roland Schirman
Washington State University - Retired
PO BOX 181
Dayton, WA 99328-0181
schirman@innw.net

Paul Schmitzer
Corteva Agriscience
9330 Zionesville Road
Indianapolis, IN 46268
prschmitzer@dow.com

Marty Schraer
Syngenta Crop Protection
152 E Cassidy Drive
Meridian, ID 83646
marty.schraer@syngenta.com

Brandon Schrage
FMC Agricultural Solutions
115 Mitchell Street
Bradshaw, NE 68319
brandon.schrage@fmc.com

Jill Schroeder
New Mexico State University
1331 S. Eads St., Apt 414
Arlington, VA 22202
jischroe1@gmail.com

Whitney Schultz
Panhandle Res & Extension Center
1702 5th Avenue
Scottsbluff, NE 69361
wschultz2@unl.edu

Brady Schulzetenberg
West Central Distribution
1761 2nd ST SE
Goodrich, ND 58444
bschulzetenberg@wcdst.com

Brian Schutte
New Mexico State University
945 College Drive
Las Cruces, NM 88003
bschutte@nmsu.edu

Dennis Scott
FMC Ag Solutions
1835 Sagewood Loop
Richland, WA 99352
dennis.scott@fmc.com

Derek Sebastian
Bayer CropScience, LP
2114 18th Street Road
Greeley, CO 80631
derek.sebastian@bayer.com

James Sebastian
Boulder County Parks &Open Space
5201 St. Vrain Rd
Longmont, CO 80503
jsebastian@boudercounty.org

Rachel Seedorf
Colorado State University
307 University Ave
Fort Collins, CO 80523-1177
rseedorf@yahoo.com

Steven Seefeldt
Washington State University
16650 SR 536
Mount Vernon, WA 98273
seefeldt@wsu.edu

Tim Seipel
Montana State University
706 Leon Johnson Hall
Bozeman, MT 59717
timothy.seipel@montana.edu

Rosalie Sepesy
Utah State University
4800 Old Main Hill
Logan, UT 84322
rose.sepesy@aggiemail.usu.edu

Tye Shauck
BASF
PO Box 517
Roslyn, WA 98941
tye.shauck@basf.com

Josh Shorb
Park County Weed & Pest Control District
1067 Road 13
Powell, WY 82435
jshorb@parkcountyweeds.org

Anil Shrestha
California State University
2415 E San Ramon Ave M/S AS72
Fresno, CA 93740-8033
ashrestha@csufresno.edu

Chandrima Shyam
Kansas State University
3719 Throckmorton PSC
Manhattan, KS 66506
chandrima@ksu.edu

Jordan Skovgard
University of Wyoming
1000 E. University Ave
Laramie, WY 82071
jordanskovgard95@gmail.com

Byron Sleugh
Corteva Agriscience
9330 Zionsville Rd
Indianapolis, IN 46268
bbsleugh@dow.com

Helen Sofaer
U.S. Geological Survey
2150 Centre Ave Bldg C
Fort Collins, CO 80526
hsofaer@usgs.gov

Neeta Soni
Colorado State University
1177 Campus Delivery
Fort Collins, CO 80523
Neeta.Soni@colostate.edu

David Spak
Bayer
403 Sir Walker Lane
Cary, NC 27519
david.spak@bayer.com

Crystal Sparks
Colorado State university
1177 Campus Delivery
Fort Collins, CO 80523-1177
cdsparks@rams.colostate.edu

John Spring
Colorado State University
315 Cedar, Ste. 100
Julesburg, CO 80737
john.spring@colostate.edu

Lauren Stanko
Utah State University
4800 Old Main Hill
Logan, UT 84322
laurenbs514@gmail.com

Gail Stratman
FMC Ag Solutions
12342 N Road
Stromsburg, NE 68666
gail_stratman@fmc.com

William Stump
University of Wyoming
Plant Sciences- Dept 3354
1000 E University Ave
Laramie, WY 82071
wstump@uwyo.edu

Joe Swanson
Boulder County Parks & Open Space
5201 St. Vrain Rd
Longmont, CO 80503
jswanson@bouldercounty.org

Hudson Takano
Colorado State University
1600 W Plum St, Apr 30d
Fort Collins, CO 80521
hudsontakano@gmail.com

Siyuan Tan
BASF Corporation
3115 Bluff Oak Dr
Cary, NC 27519
siyuan.tan@basf.com

Kristen Tanz
Colorado State University
1177 Campus Delivery,
Fort Collins, CO 80523
kristen.tanz@gmail.com

Daniel Tekiela
University of Wyoming
1000 E Univeristy Ave
Laramie, WY 82071
dtekiela@uwyo.edu

Nickolas Theisen
North Dakota State University
Dept 7670
PO Box 6050
Fargo, ND 58108-6050
nickolas.theisen@ndus.edu

Dani Thiemann
Utah State University
Champ Dr
Logan, UT 84322
thiemannd1@gmail.com

Alexis Thompson
University of Idaho
3806 N 3600 E
Kimberly, ID 83341
athompson@uidaho.edu

Olivia Todd
Colorado State University
1177 Campus Delivery
Fort Collins, CO 80523
oetodd@gmail.com

Kelly Uhing
Denver Natural Resources
201 W. Colfax Ave., Dept. 605
Denver, CO 80202
Kelly.uhing@denvergov.org

Kai Umeda
University of Arizona
4341 East Broadway
Phoenix, AZ 85040
kumeda@cals.arizona.edu

Darren Unland
BASF
232 South Bend Drive
Durham, NC 27713
darren.unland@basf.com

Jared C Unverzagt
BASF
83 Baldy Ct
Bozeman, MT 59718
jared.unverzagt@basf.com

Stephen Valenti
Bayer Crop Science
5132 Rosecreek PKWY
Fargo, ND 58104
treeoflibertyone@gmail.com

Stephen Van Vleet
Washington State University
310 N. Main St., Room 209
Colfax, WA 99111
svanvleet@wsu.edu

Jim Vandecoevering
BASF Corporation
5000 N. Rivervista Way
Garden City, ID 83714
jim.vandecoevering@basf.com

Joseph Vassios
UPL NA, Inc.
5024 Brightside Ln
Roseville, CA 95661
joseph.vassios@uniphos.com

John Vickery
Ark Ecological Services
6560 Dover ST
Arvada, CO 80004
jvickery@mcg.net

Dave Vos
South Dakota State University
235 Berg Ag Hall
Brookings, SD 57007
dave.vos@sdstate.edu

Jacob Watt
Research Associate
4181 District 5 Road
Bonners Ferry, ID 83805
jake.watt@hubbardagscience.com

Stephanie Wedryk
Rx Green Technologies
5350 Joliet Street Unit 2
Denver, CO 80239
swedryk01@gmail.com

Jafe Weems
Syngenta Crop Protection
2307 W. 29th Ave
Kennewick, WA 99337
jafe.weems@syngenta.com

Eric Westra
Colorado State University
1177 Campus Delivery
Fort Collins, CO 80523
epwestra@rams.colostate.edu

Henry Wetzel
Washington State University
P.O. Box 646420
Pullman, WA 99164-6420
henry_wetzel@wsu.edu

Alix Whitener
FMC
3010 Riverview Lane
Malaga, WA 98828
alix.whitener@fmc.com

Cheryl Wilen
UCCE
9335 Hazard Way Ste. 201
Lake Forest, CA 92630
cawilen@ucanr.edu

Malcolm Wiley
Boulder County Parks & Open Space
5201 St. Vrain Rd
Longmont, CO 80503
mwiley@bouldercounty.org

Mike Wille
450 N 2nd Streey Rm 325
Lander, WY 82520
mwille@wyoming.com

Gary Willoughby
North Central Rea Extension Center
5400 Hi. 83 S
Minot, ND 58701
gary.willoughby@ndsu.edu

MeiLing Wong
Montana State University
Leon Johnson Hall
Bozeman, MT 59715
meiling.wong@student.montana.edu

Joseph Wood
New Mexico State University
1780 E University Ave
Las Cruces, NM 88003
joewood@nmsu.edu

Ramawatar Yadav
748, Railroad Hwy
Huntley, MT 59037
ramawatar.yadav@montana.edu

Jaime Yanes
Albaugh, LLC
949 Winleaf Dr
Collierville, TN 38017
JaimeY@albaughllc.com

Joe Yenish
Corteva AgriSciences
1001 Calendula Circle
Billings, MT 59105
joe.yenish@corteva.com

Patty York
Colorado Dept. of Agriculture
305 Interlocken Pkwy.
Broomfield, CO 80021
patty.york@state.co.us

Steve Young
Dept. of Plants, Soils & Climate
Logan, UT 84322
steve.young@usu.edu

Dan Zapotok
Bayer Crop Sciences
5000 Centergreen Way
Cary, NC 27513
daniel.zapotok@bayer.com

Rich Zollinger
Amvac Chemical Company
4305 S Big Horn Lane
Spokane Valley, WA 99206-7044
richardz@amvac-chemical.com

Rachel Zuger
Washington State University
P.O. Box 646420
Pullman, WA 99164-6420
rachel.zuger@wsu.edu

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