‘Unofficial’ NCWSS 2021 Proceedings

NCWSS

North Central
Weed Science Society

These abstracts are being made available as early as possible prior to the NCWSS annual meeting via this ‘unofficial’ proceedings document for those that prefer access to the abstracts prior to start of the meeting. The abstracts will also be available in the meeting app “Crowd Compass”.

Following the meeting, the **‘Official’ 2021 NCWSS Proceedings** will be published and made available to the public to be used as the historical record for the society and to provide and a citable source document.

NCWSS Members' Vision for Continued Success. Sarah Lancaster*[1], Erin Haramoto[2], Alyssa Essman[3], Cody Evans[4], Justin Pollard[5], Debalin Sarangi[6], Daniel H. Smith[7], Nader Soltani[8]; [1]Kansas State University, Manhattan, KS, [2]University of Kentucky, Lexington, KY, [3]The Ohio State University, Columbus, OH, [4]Bayer Crop Science, Franklin, IL, [5]Bayer Crop Science, Lathrop, MO, [6]University of Wyoming, Laramie, WY, [7]University of Wisconsin-Madison, Madison, WI, [8]University of Guelph, Ridgetown, ON, Canada (2)

NCWSS members were surveyed during May 2021 to assess how well the society is meeting members' expectations for meetings and other services. Members were asked to provide feedback on the annual meeting and membership in general. Lastly, demographic data was collected to examine the backgrounds of members. The survey was distributed via the NCWSS membership email. A total of 201 individuals began the survey, an initial response rate of 23%; 153 individuals completed the entire survey, including the demographic and informational questions. Of these 153, 43% indicated that they have been NCWSS members for > 20 years. A similar percentage have been NCWSS members for 10 or fewer years. Approximately one-third of the respondents were more than 60 years old, with a similar fraction less than 40 years. Over 80% of respondents identify as male, with a majority (65%) of female respondents being relatively newer NCWSS members (< 10 years). Over 67% of members received an undergraduate degree in agronomy or crop science, with other reported majors including (in descending order) soil science, biology, plant science, and horticulture. Only 12% of respondents had no agricultural experience as a child. Over 90% of respondents considered technical information about weed management and professional networking to be very important aspects of membership, and approximately 70% of respondents believed the society is extremely effective at providing those benefits. These were among the most commonly named benefits of attending the annual meeting. Accordingly, many respondents suggested changes that would facilitate greater access to information and more opportunities for interactions among members. Mentoring was identified as a very important aspect of membership by approximately 50% of respondents; however, only 18% believe the society is very effective in facilitating this benefit. Over 60% of respondents identified the newsletter as the most effective means of society communication, followed by the website. Respondents indicated a need to update the society website and requested emails be more frequent and concise. Most members (~57%) reported that they do not use Twitter. It was suggested, however, as a tool for engaging with the public, although many respondents indicated that this should be discussed strategically first, specifically in terms of how it aligns with our organizational goals and our relationship with WSSA. Improvements suggested by respondents included better communication from NCWSS to members as well as facilitating communication between members. Specific suggestions included a more dynamic newsletter, specific members-only content on the website, more frequent website updates, and social media posts. Other suggestions included meetings to highlight emerging issues. Members also wanted more mentorship opportunities, specifically opportunities beyond the annual meeting--echoing the perception that the society is not very effectively providing these opportunities. Lastly, respondents wanted NCWSS to establish a stronger regional presence, potentially hosting the region's go-to pages for weed identification, resistance issues, and other topics.

Weed Control in Corn with Residual Herbicides Applied Preemergence. Tatiane S. Silva*[1], Nicholas J. Arneson[1], Daniel H. Smith[1], Ryan P. DeWerff[1], Daniel V. Silva[2], Rodrigo Werle[1]; [1]University of Wisconsin-Madison, Madison, WI, [2]Federal Rural University of the Semi-Arid Region, Mossoro, Brazil (8)

The increase in herbicide-resistant weeds in the United States is challenging producers to search for and adopt alternative weed control strategies. The use of effective PRE-emergence herbicides help maintain fields free of weeds at the beginning of the season, protecting crop yield when weeds are the most competitive. Field experiments were conducted in 2021 at Janesville and Lancaster, WI to evaluate the residual efficacy of multiple PRE herbicides in corn. Treatments consisted of 14 PRE herbicides plus a nontreated control: atrazine, simazine, acetochlor, *S*-metolachlor, mesotrione, acetochlor + mesotrione, *S*-metolachlor + atrazine, acetochlor + atrazine, saflufenacil + dimethenamid-P, clopyralid + flumetsulam, bicyclopyrone + mesotrione + *S*-metolachlor, bicyclopyrone + mesotrione + atrazine + *S*-metolachlor, acetochlor + clopyralid + flumetsulam, and acetochlor + clopyralid + mesotrione. At 6 weeks after treatment (WAT), visual control (0-100%) and weed biomass were collected at both locations. At Janesville, the giant ragweed (*Ambrosia trifida* L.) infestation was high, consequently, only saflufenacil + dimethenamid-P, bicyclopyrone + mesotrione + *S*-metolachlor, bicyclopyrone + mesotrione + atrazine + *S*-metolachlor and acetochlor + clopyralid + mesotrione provided relatively effective levels of residual giant ragweed control (71-78%) with biomass reduction of 66-77% compared with the nontreated control at 6 WAT. The remaining herbicide treatments resulted in low levels of giant ragweed control (<65%) and biomass reduction (<50%). At Lancaster, waterhemp [*Amaranthus tuberculatus* (Moq.) J.D. Sauer] control by atrazine and clopyralid + flumetsulam treatments was ineffective (<50% for control and biomass reduction) at 6 WAT. On the other hand, the remaining treatments provided effective control (70-100%). Common lambsquarters (*Chenopodium album* L.) control was >77% and the biomass reduction was >65% for all herbicide treatments when compared to the nontreated control at 6 WAT. These field studies suggest that PRE-herbicides should be considered in weed management programs to reduce the initial weed competition, particularly when small seeded broadleaf species such as waterhemp and common lambsquarters are present in the soil seedbank. Thus, the predominant weed species present in the soil seedbank should be understood and considered to support the selection of effective PRE herbicide programs.

Precipitation and Temperature Effects on Group 15 Herbicides. Tyler P. Meyeres*, Lily A. Woitaszewski, Chad J. Lammers, Malynda M. Smith, Sarah Lancaster; Kansas State University, Manhattan, KS (9)

As weather patterns change and herbicide resistant weeds continue to challenge producers, it is important to characterize the effect of environment on the control of herbicide resistant weeds and efficacy of residual herbicides. The objective of this trial was to compare the impact of environmental conditions on the efficacy of group 15 herbicides when applied at various simulated corn planting times and the subsequent effect on control of troublesome weeds in Kansas. To fulfill this objective, a bare ground field experiment was conducted in Manhattan, Kansas in 2021. The experiment included four herbicides applied at five different dates. The herbicides applied included acetochlor (1682 g ai ha^{-1}), S-metolachlor (2142 g ai ha^{-1}), dimethenamid-p (1104 g ai ha^{-1}), and pyroxasulfone (219 g ai ha^{-1}). Herbicides were applied on April 14, April 29, May 14, June 4, and June 18, 2021. Data loggers were also used to collect soil temperature and soil moisture. The dominant weed species was Palmer amaranth (*Amaranthus palmeri* S. Watson). Weed control was visually assessed 2, 4, and 8 weeks after treatment (WAT). Palmer amaranth height was collected at each evaluation timing. Weed density and biomass were collected 8 WAT for all weed species present in plots. Within seven days after applications (DAA) were made on April 14, April 29, May 14, June 4, and June 18 plots received 1.6, 0.05, 10.1, 0, 0.3 cm of precipitation and averaged 14.84, 206.47, 450.29, 948.05, 1498.13 accumulated soil growing degree days, respectively. All data were analyzed with ANOVA and means were separated with Tukey's HSD test (a = 0.10) using base R and R package agricolae. There were no differences 2 WAT for Palmer amaranth control across application dates and herbicides. Four WAT there was a significant effect of application date, but due to the conservative nature of the Tukey's HSD test there were no differences reported among application dates. Herbicide and application date effected Palmer amaranth control 8WAT. Acetochlor applied on May 14 resulted in low levels of Palmer amaranth control (42%) 8 WAT and resulted in significantly less control than herbicides applied on April 14 and 29. Poor control resulting from acetochlor applied on May 14 could be attributed to the water-soluble (223 mg L^{-1}) nature and high adsorptivity (K_{oc}=200) of acetochlor and large amount of precipitation received within 7 DAA. Weed biomass was greater 8 WAT when herbicides were applied on June 18 than when applied on April 14, April 29, and June 4, regardless of herbicide applied or weed species. Applications occurring on June 18 resulted in a shorter amount of time for Palmer amaranth to reach 10 cm than applications on April 29. The differences in Palmer amaranth growth may be attributed to the rapid accumulation of soil growing degree days following application on June 18. These data can help producers adjust residual herbicide selection to best match environmental conditions early in the growing season.

Spray Volume Effects on Residual Herbicide Efficacy in Corn. Tyler P. Meyeres*[1], Lily A. Woitaszewski[1], Malynda M. Smith[1], Christopher Mayo[2], Sarah Lancaster[1]; [1]Kansas State University, Manhattan, KS, [2]Bayer CropScience, Salina, KS (10)

Residual herbicides are an important component in corn cropping systems and are a key tool to control herbicide resistant weeds. The recent characterization of 6-way resistant Palmer amaranth (*Amaranthus palmeri* S. Watson) makes it critical to optimize application parameters surrounding residual herbicides and there are many avenues to pursue regarding those parameters. The objective of this trial is to quantify the effects of residual herbicide applications in corn as influenced by application timing and spray volume on weed control. Field experiments were conducted in Colby, KS and in Ottawa, KS in 2021. Corn was grown under irrigation in Colby and under dryland conditions in Ottawa. Growing conditions and stand establishment was poor in Ottawa, KS due to excess precipitation and excellent in Colby. Each experiment included two early postemergence (EPOST; V2) herbicide tank mixes: Resicore (133 g ae ha^{-1} clopyralid + 1962 g ai ha^{-1} acetochlor + 210 g ai ha^{-1} mesotroine) + 1262 g ae ha^{-1} glyphosate + 1634 g ai ha^{-1} atrazine; and TriVolt (75 g ai ha^{-1} isoxaflutole + 30 g ai ha^{-1} thiencarbazone-methyl + 375 g ai ha^{-1} flufenacet) + 1262 g ae ha^{-1} glyphosate + 1634 g ai ha^{-1} atrazine applied at three different carrier volumes (56, 122, and 187 L ha^{-1}) as either EPOST only or EPOST *followed by* late post emergence (LPOST; 280 g ae ha^{-1} dicamba + 112 g ai ha^{-1} diflufenzopyr + 1262 g ae ha^{-1} glyphosate at 140 L ha^{-1} , 91 cm/V8). The LPOST application was not applied in Colby as the corn was beyond growth stage and height restrictions. The dominant weed species were Palmer amaranth in Colby and common waterhemp (*Amaranthus tuberculatus* [Moq.] Sauer) and fall panicum (*Panicum dichotomiflorum* Michx.) in Ottawa. Weed control ratings were taken at 4 and 8 WAT (weeks after treatment) and at harvest. All data were analyzed with ANOVA and means were separated with Tukey's HSD test using R and alpha = 0.10 was utilized. Palmer amaranth averaged 94% control across all evaluation timings. Fall panicum control was greater than 90% in all treatments 4 weeks after EPOST and LPOST applications. TriVolt resulted in greater fall panicum control than Resicore 8 weeks after EPOST. Eight weeks after LPOST , Resicore applied at 187 L ha^{-1} resulted in greater control than treatments applied 56 L ha^{-1}. In general, Resicore applied at 187 L ha^{-1} and TriVolt applied at 56 L ha^{-1} resulted in greater than 90% control at 4 and 8 weeks after the EPOST and 4 WAT of the LPOST. At 8 weeks after the LPOST, common waterhemp control averaged 79% across all treatments. Weed control at harvest was greater when EPOST applications were followed by LPOST applications Conditions during and following applications maybe an indicator of the performance of certain residual herbicides applied at varying spray volumes. Under good conditions, low spray volumes may be utilized without compromising weed control, but under challenging environmental conditions producers may need to be more strategic in the selection of residual herbicides and spray volumes.

Comparative Effects of Herbicide, Nitrogen Inhibitors, and Nitrogen Source on Nitrification and Corn Yield. William H. Neels*, Amit J. Jhala, Bijesh Maharjan, Richard Little, Javed Iqbal; University of Nebraska-Lincoln, Lincoln, NE (11)

Nitrogen management in crops can be challenging due to nitrogen transformations and losses in soil, such as nitrification and denitrification. Nitrification is the conversion of ammonium (NH_4^+) to nitrate (NO_3^-) by ammonia oxidizing bacteria (AOB), *Nitrosomonas* and *Nitrobacter*. Nitrates can be lost through leaching during heavy precipitation. Nitrification inhibitor products are used to temporarily slow the nitrification process by reducing the abundance of AOB populations. Herbicides can also generate non-target effects on soil microorganisms and can be used as an alternative to slow the nitrification process. Several studies have been conducted in laboratory settings to observe effects of herbicides on nitrification and nitrate leaching. However, the effect of herbicide on nitrification in field corn (*Zea mays*) production remains uncertain. A field experiment was conducted at the University of Nebraska-Lincoln South Central Agricultural Laboratory. Treatments were laid out in a split-plot factorial design with 4 replications. The main plot factor included 3 herbicide treatment levels. The subplot factor included 5 fertilizer treatment levels. Throughout the growing season, weekly soil samples were collected to determine the treatment effect on nitrification. Herbicide applications did not decrease nitrification at a significant level. Anhydrous ammonia with nitrapyrin generally decreased nitrification and retained ammonium concentrations compared to anhydrous ammonia without nitrapyrin, with significant effects observed at 14 DAT. Similarly, urea with dicyandiamide decreased nitrification and retained ammonium concentrations than urea without dicyandiamide, with significant effects observed at 21 DAT. Nitrogen treatments containing anhydrous retained ammonium concentrations at significantly higher levels when compared to urea treatments.

Control of Glyphosate/glufosinate/dicamba-resistant Soybean Volunteers in Corn with Pre-emergence Herbicides. Mandeep Singh*, Amit J. Jhala; University of Nebraska-Lincoln, Lincoln, NE (12)

Soybean volunteers have not been a serious issue; however, it can be a problem weed in certain conditions such as when growers do not harvest soybean due to hail or windstorm. In addition, commercial cultivation of soybean resistant to dicamba/glufosinate/glyphosate reduce herbicide options for controlling soybean volunteers. The objectives of this study were to evaluate efficacy of labeled PRE corn herbicides for control of dicamba/glufosinate/glyphosate-resistant (XtendFlex) soybean volunteers in Enlist™ corn and their effects on corn injury and yield. A field experiment was conducted in 2021 at South Central Ag Lab, University of Nebraska, Clay Center, NE. Dicamba/glufosinate/glyphosate-resistant soybean harvested from the previous season was cross-planted at 125,000 seeds ha^{-1} to mimic soybean volunteers. After 2 days, Enlist™ corn was planted at 87,500 seeds ha^{-1} and PRE corn herbicides were applied on the same day. Acetochlor/clopyralid/flumetsulam, acetochlor/clopyralid/mesotrione, and atrazine/bicyclopyrone/mesotrione/*S*-metolachlor provided 75%-97% and 83%-99% control of soybean volunteers with no corn injury at 28 and 42 d after PRE, respectively. Isoxaflutole applied alone and isoxaflutole/thiencarbazone-methyl mixed with atrazine provided 63%-70% and 75%-78% control of soybean volunteers at 28 and 42 d after PRE, respectively. Corn yield was not affected by competition of soybean volunteers in any of the treatment. The results demonstrate that PRE herbicides with multiple sites of action are available for effective control of dicamba/glufosinate/glyphosate-resistant soybean volunteers in corn.

Maverick™™: A New Herbicide Premix for PRE and POST Weed Control in Corn.
Garrison J. Gundy*[1], John Pawlak[2], Lowell Sandell[3], Jonathon Kohrt[4], Eric Ott[5], Trevor Israel[6], Ron Estes[7]; [1]Valent USA LLC, Seymour, IL, [2]Valent USA LLC, Lansing, MI, [3]Valent USA LLC, Ashland, NE, [4]Valent USA LLC, West Des Moines, IA, [5]Valent USA LLC, Greenfield, IN, [6]Valent USA LLC, Harrisburg, SD, [7]Valent USA LLC, Tolono, IL (13)

Maverick™ Corn Herbicide is a new three-way premix, consisting of mesotrione, clopyralid, and pyroxasulfone, currently being developed by Valent USA LLC. Maverick Corn Herbicide has a relatively low use rate compared to many of the corn products currently available and can be applied preplant incorporated, preemergence, postemergence, or as a sequential-split application. Maverick Corn Herbicide is effective on a broad range of broadleaf and grass weed species, including problematic weeds like Palmer amaranth (*Amaranthus palmeri*), common waterhemp (*Amaranthus tuberculatus*), common lambsquarters (*Chenopodium album*), and fall panicum (*Panicum dichotomiflorum*). Field research trials conducted over the past three years with Maverick Corn Herbicide applied preemergence resulted in similar levels of weed control compared to Resicore® (Corteva Agriscience™) when applied at labelled use rates. In the same trials the addition of atrazine (840 g ai ha^{-1}) to Maverick Corn Herbicide resulted in the same level of weed control as Acuron® (Syngenta). Maverick Corn Herbicide also controls a broad spectrum of many prevalent weeds in the Midwest when applied postemergence. The addition of atrazine and/or glyphosate can broaden the weed spectrum and improve overall efficacy of Maverick Corn Herbicide when applied to emerged weeds. Maverick Corn Herbicide is currently pending EPA registration.

Control of Multiple Herbicide-Resistant Palmer Amaranth (*Amaranthus palmeri*) in Corn Resistant to 2,4-D Choline/Glufosinate/Glyphosate. Ramandeep Kaur*[1], Vipan Kumar[2], Stevan Knezevic[3], Nevin Lawrence[4], Rachana Jhala[1], Amit J. Jhala[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]Kansas State University, Manhattan, KS, [3]University of Nebraska Lincoln, Concord, NE, [4]University of Nebraska Lincoln, Scottsbluff, NE (14)

Multiple herbicide-resistant Palmer amaranth is among the most problematic summer annual broadleaf weeds across the mid-south, southeastern, and north central United States. Palmer amaranth has evolved to number of herbicide sites of action. A new multiple herbicide-resistant corn trait resistant to 2,4-D choline, glufosinate, and glyphosate, also known as Enlist corn, has been developed and commercially available from 2019 growing season in the United States. The objective of this study was to evaluate the effect of herbicide programs applied PRE, early-POST (EPOST) and late-POST (LPOST) for ALS inhibitors/atrazine/glyphosate-resistant Palmer amaranth control, and yield in corn resistant to 2,4-D choline/glufosinate/glyphosate. Field experiments were conducted near Carleton, NE, in 2020 and 2021 in a grower's field infested with ALS-inhibitors/atrazine/glyphosate-resistant Palmer amaranth. Averaged across herbicide programs, acetochlor/mesotrione/clopyralid applied PRE or followed by (fb) 2,4-D choline, acetochlor/flumetsulam/clopyralid fb 2,4-D, flufenacet/isoxaflutole/thiencarbazone-methyl fb 2,4-D choline, acetochlor/flumetsulam/ clopyralid fb glufosinate and flufenacet/isoxaflutole/ thiencarbazone-methyl fb glufosinate provided higher grain yield and 95% to 99% control of ALS inhibitors/atrazine/glyphosate -resistant Palmer amaranth. The results of this research illustrate that herbicide programs are available for the control of multiple herbicide resistant Palmer amaranth in corn resistant to 2,4-D choline/glufosinate/glyphosate.

Evaluating Greenhouse Corn Preemergence Herbicide Carry Over Potential to Interseeded Cover Crops. Victor de Sousa Ferreira*[1], Christopher Proctor[1], Breno Nyssen[1], Thiago H. Vitti[1], Rodrigo Werle[2], Tatiane S. Silva[2], Bruno Canella Vieira[2]; [1]University of Nebraska Lincoln, Lincoln, NE, [2]University of Wisconsin-Madison, Madison, WI (15)

The adoption of cover crops as a strategy to improve soil health and cropping systems sustainability is on the rise in the United States. The application of PRE herbicides with soil residual activity is commonly used in corn production systems in order to reduce early season weed establishment and minimize crop-weed competition and yield loss. Active ingredients from preemergence herbicides, when sprayed on the field, remain in the soil rhizosphere for a period of time killing weed seedlings as they emerge. However, PRE herbicides can also impact the establishment of interseeded cover crops. A series of greenhouse dose response and establishment time bioassays are being conducted in Lincoln, NE to evaluate the impact of commonly used corn PRE herbicides on interseeded cover crops. The main objective of these studies is to elucidate the impact of corn PRE herbicides on cover crop establishment and to identify the ideal time to interseed cover crops following herbicide application. For both experiments, PRE herbicide treatments consist of atrazine + S-metolachlor + bicycloprione + mesotrione (Acuron), acetochlor + mesotrione + clopyralid (Resicore), and saflufenacil + dimethenamid (Verdict). For the dose response experiments, six rates (1x, 0.8x, 0.6x, 0.4x, 0.2x and 0x relative to herbicide label recommendation) are being evaluated whereas for the timing of establishment following application, the 1X label rate is being evaluated. Bioindicator species being evaluated in this study include hairy vetch (*Vicia villosa*), cereal rye (*Secale cereale*), winter wheat (*Triticum aestivum*), radish (*Raphanus sativus*), red clover (*Trifolium pratense*) and annual rye (*Lolium multiflorum*) as cover crops, and Palmer amaranth (*Amaranthus palmeri*) and giant foxtail (*Setaria faberi*) as weeds. Biomass reduction compared to the control will be presented and used to estimate the time required from herbicide application until cover crops can be safely interseeded. Further on-farm field research will be conducted in 2022 and 2023 to validate the learnings from our greenhouse bioassays before recommendations are shared with growers interested in interseeding cover crops.

Effect of Spray Volume and Weed Height on Palmer Amaranth (*Amaranthus palmeri)* and Large Crabgrass (*Digitaria sanguinalis*) Control by Tank Mixes Used in 2,4-D Resistant Soybeans. Chad J. Lammers*, Malynda M. Smith, Tyler P. Meyeres, Kraig Roozeboom, Sarah Lancaster; Kansas State University, Manhattan, KS (16)

Herbicide co-application increases farm efficiency and facilitates control of a broader spectrum of weed species. However, application requirements may conflict or weed control may be reduced when herbicides are co-applied. Enlist E3 soybeans are resistant to postemergence application of 2,4-D choline, glyphosate, and glufosinate, making co-application of these products during the soybean growing season possible. However, reduced efficacy has been documented when some combinations of these products are applied to grasses. A greenhouse experiment was conducted to determine large crabgrass (*Digitaria sanguinalis* L.) and Palmer amaranth (*Amaranthus palmeri* S. Watson) control by 2- and 3-way combinations of 2,4-D (1064 g ai ha^{-1}), glufosinate (655 g ai ha^{-1}), and glyphosate (862 g ae ha^{-1}). Each treatment included ammonium sulfate (3,351 g ai ha^{-1}) and was applied with carrier volumes of 93-, 140-, and 187-L ha^{-1} to 5-, 10-, and 20- cm large crabgrass and Palmer amaranth. Treatments were randomized in a split-split plot design according to replication and plant height at application. Water sensitive paper was also sprayed at the different carrier volumes and with the different tank mixes to determine the number of droplets and percent area covered. At 4 weeks after treatment, visual ratings and above ground biomass were collected. Data were subjected to analysis of variance and means separation (Tukey's pairwise comparisons, a=0.05). Control for all treatments for large crabgrass ranged from 12 to 100%. Large crabgrass control was $\geq$ 82% when treatments were applied at 5 cm, but control of 10- or 20- cm large crabgrass was reduced. Large crabgrass control was similar for all carrier volumes. Control for all Palmer amaranth treatments ranged from 6 to 100%. Palmer amaranth control was similar for all carrier volumes. Palmer amaranth control at 5-, 10- and 20 cm was 100%, $\geq$96%, and $\geq$34%, respectively. 2,4-D + glyphosate provided the greatest Palmer amaranth control. There was a carrier volume by herbicide tank mix interaction for the number of droplets deposited and percent area covered on water sensitive paper. Tank mixes containing glufosinate had more droplets than those not containing glufosinate. 2,4-D+glyphosate had the smallest percent area covered, compared to the other herbicide tank mixes. These data suggest that under ideal conditions, carrier volume has a limited effect on control of large crabgrass and Palmer amaranth and control was not related to spray deposition.

Planting Soybean "Green" -- Supplemental Nitrogen, Yield Response and Weed Management Implications. Mark L. Bernards*, Brent S. Heaton, Kinsey E. Tiemann; Western Illinois University, Macomb, IL (17)

The use of cover crops has become increasingly important for weed and nutrient management within corn (*Zea mays*) and soybean (*Glycine max*) cropping systems. Planting soybeans before terminating rye (*Secale cereal*) may increase weed suppression, but may also reduce soybean yield. Applying supplemental nitrogen to soybean planted into green rye may minimize potential yield loss, but may also increase weed growth. Our objective was to measure weed growth and soybean yield as affected by cereal rye termination time and the addition of supplemental nitrogen at planting. Two studies were conducted in both 2020 and 2021. The first study was maintained weed-free to measure soybean growth and yield response, and in the second weeds were allowed to grow with the crop for 6 weeks to measure weed density and biomass. Rye was terminated 2 weeks before or 0 or 2 weeks after soybean planting using glyphosate. Nitrogen was applied at 0, 22, 44, or 66 kg ha^{-1} at soybean planting. Soybean yield was not affected by nitrogen rate, but weed biomass at 6 weeks after planting was increased by 44 and 66 kg ha^{-1} supplemental nitrogen. Soybean yield was not reduced by planting green when the rye was terminated at planting, but yield was reduced when rye termination was delayed until 2 weeks after planting in 2020. Similarly, weed density and biomass were reduced by delaying rye termination until 2 weeks after planting. Planting soybean into green cover crops is a valuable weed management tool, but work is still needed to understand causes of soybean yield loss from cover crop interference and ways to mitigate that interference.

Hyperspectral Imaging for Early Detection of Herbicide-Resistant *Amaranthus tuberculatus* in Soybean Production Fields. Austin H. Schleich*[1], Prashant Jha[1], Joseph Shaw[2], Bryan Scherrer[2], John Sheppard[2], Ramawatar Yadav[1], Alexis L. Meadows[1], Avery J. Bennett[1], Ryan Hamberg[1], Edward S. Dearden[1]; [1]Iowa State University, Ames, IA, [2]Montana State University, Bozeman, MT (18)

Weeds are continuously evolving and are becoming increasingly difficult to control due to herbicide resistance (HR). Multiple HR waterhemp [*Amaranthus tuberculatus* (Moq.) J.D Sauer] populations have evolved creating serious management issues in corn and soybean fields. Herbicide dose-response screening has been an effective way to detect HR in weed species; however, this process can be very time consuming, taking weeks or months. By utilizing hyperspectral imaging, HR weed biotypes can be detected (real-time) in a more efficient and timely manner. Experiments were conducted in 2021 to determine if hyperspectral imaging can be used to detect HR waterhemp biotypes early in the season in soybean production fields. The objectives of this research were to: (1) differentiate waterhemp plants from other weed species present in the field; and (2) within those waterhemp plants, identify different biotypes and their HR status. Hyperspectral imaging was performed using ground- and UAV-based platforms. HR [resistance to ALS inhibitors, PS II inhibitors, EPSPS inhibitor (glyphosate), PPO inhibitors, and HPPD inhibitors] and susceptible waterhemp biotypes were grown in the Iowa State University Agronomy greenhouse in Ames, IA during the spring of 2021 to develop calibration images. When waterhemp reached a height of 10 cm, imaging was conducted utilizing a Pika L Hyperspectral Imager under artificial lighting. Field experiments were conducted in June of 2021 in soybean fields near Ames, IA. The Pika L Imager was mounted onto a DJI M600Pro drone. Drone flights occurred over soybean fields with known HR waterhemp populations. Spectral data were extracted from the Pika L imager using a Resonon software *Spectronon Pro* to develop classification images using a neural network (machine learning algorithm). A PCA plus logistic regression code was used in *Python* to analyze the spectral data. Waterhemp was differentiated from other weedy species with 81% accuracy. One-way HR to glyphosate and HPPD inhibitors was identified with 81% and 27% accuracy, respectively. Two-way HR to ALS inhibitors + PS II inhibitors, and glyphosate + ALS inhibitors were identified with 16% and 37% accuracy, respectively. Finally, three-way HR to glyphosate + ALS inhibitors + PS II inhibitors was identified with 46% accuracy. Results for HPPD resistance, two-way resistance, and three-way resistance were less consistent, and would require further evaluation to achieve classification accuracies >80%. Overall, the results indicate that hyperspectral imaging and neural networks hold promise for early detection of herbicide-resistant weed biotypes in soybean production fields, especially GR biotypes. This will ultimately lead to development of UAV-based weed maps for timely implementation of integrated weed management (IWM) programs for managing HR weeds in crop production fields.

Kyber Clean: an Effective Solution for Managing Resistant Weeds in Enlist Soybean. Kelly A. Backscheider*, Joe Armstrong, David M. Simpson, Kevin Johnson, Kristin Rosenbaum, Dave Johnson, Frances Meeks; Corteva Agriscience, Indianapolis, IN (19)

Kyber™ herbicide is a new Corteva Agriscience™ preemergence herbicide that contains three modes of action, pyroxasulfone, flumioxazin, and metribuzin. Kyber™ was launched commercially in 2020 and is an effective preemergence herbicide in an Enlist® soybean program. Trials were conducted in 2021 to evaluate the crop response and weed control with Kyber™ in Enlist® herbicide programs. Minimal (<10%) crop response was observed with Kyber™ applied when evaluated across several conventional tillage and no-till locations. When used in the Enlist® weed control system, Kyber™ herbicide provided early season residual control of glyphosate-resistant waterhemp (*Amaranthus tuberculatus*), Palmer amaranth (*Amaranthus palmeri*), and kochia (*Bassia scoparia*) with a single postemergence application of 2,4-D choline + glyphosate or glufosinate resulting in season long weed control. Kyber™ herbicide with three modes of action will be an important resistant management tool when used with Enlist® soybean or other soybean herbicide traits.

Cover Crop Termination Timing by Herbicide Interaction for Managing Glyphosate-Resistant Horseweed and Waterhemp in Soybean. Edward S. Dearden*, Prashant Jha, Ramawatar Yadav, Avery J. Bennett, Alexis L. Meadows, Austin Schleich, Ryan Hamberg; Iowa State University, Ames, IA (20)

Glyphosate-resistant horseweed (*Erigeron canadensis* L.) and waterhemp (*Amaranthus tuberculatus* [Moq.] J.D. Sauer) are the most problematic weeds in soybean across the Midwest. Field experiments were conducted in 2021 at two sites in Ames, IA and Boone, IA. A three-factor split-split plot design was used with four replications. First factor consisted of cereal rye (*Secale cereale* L.) cover crop vs. no cover crop. Second factor consisted of two timings of cover crop termination: 7 d before- or after- soybean planting (planting green). The third factor consisted of four herbicide programs, which included: 1) glyphosate (PRE) for cover crop termination only, 2) glyphosate (PRE) followed by (fb) glufosinate (POST), 3) glyphosate plus S-metolachlor and fomesafen (PRE) fb glufosinate (POST), or 4) glyphosate (PRE) fb glufosinate plus S-metolachlor and fomesafen (POST). Cereal rye had a biomass of 5,100 kg ha^{-1} at the early termination timing (7 d before soybean planting) compared with 11,800 kg ha^{-1} at the late termination timing (7 d after soybean planting). Regardless of the termination timing, the cereal rye cover crop reduced horseweed density by 90% compared with no cover crop. Similarly, at the time of POST herbicide application (5 wk after soybean planting, WAP), cover crop reduced horseweed aboveground biomass by 80% compared with no cover crop. However, at the time of soybean canopy closure (10 WAP), early terminated cover crop reduced horseweed biomass by only 55%, whereas the late-terminated cover crop reduced horseweed biomass by 90% compared with no cereal cover crop treatment. Herbicide programs did not influence horseweed density and biomass. Presence of cover crop and termination timing had a significant interaction for waterhemp density. At the time of POST herbicide application, the late-terminated cover crop reduced waterhemp density by 70%, whereas the early-termination timing reduced waterhemp density by only 55%, compared with the no cover crop plots. Regardless of the termination timing, the cereal rye cover crop reduced waterhemp biomass by 20% compared with no cover crop. Although herbicide programs alone did not influence waterhemp density, there was a significant interaction of herbicide program with cover crop and termination timing. At 10 WAP, cover crop and the PRE residual herbicide (s-metolachlor + fomesafen) applied at the time of termination reduced waterhemp density by >65% compared with no cover crop, no PRE residual herbicide, or when the residual herbicide was applied at the POST application timing. In the early-terminated cover crop, waterhemp density from the residual herbicide was 55% less when applied at the time of termination (PRE) vs. POST. However, the application timing of the residual herbicide did not influence waterhemp density in the late-terminated cover crop plots. In conclusion, delaying the cover crop termination timing until 7 d after soybean planting (planting green) along with a PRE soil residual herbicide would be an effective IWM strategy to manage herbicide-resistant weed seed banks in soybean.

Effective Respray Herbicide Options for Weeds Surviving Auxin Herbicides. Tomas F. Delucchi*, William G. Johnson, Bryan G. Young; Purdue University, West Lafayette, IN (21)

The auxin herbicide resistance traits in soybean that are available in the market today allow for use of 2,4-D or dicamba as postemergence tools to improve management of Palmer amaranth (*Amaranthus palmeri* S. Wats) and tall waterhemp [*Amaranthus tuberculatus* (Moq.) J. D. Sauer]. However, complete control of these species is not always achieved due to adverse environmental conditions, plant growth factors or poor application methods. In these instances, a subsequent postemergence herbicide is required to control any plant that survived the first auxin herbicide application. Utilizing the same herbicide that failed in the initial application for the subsequent respray does not represent a sound resistance management strategy and may not be the most effective herbicide option. However, this practice has become a common recommendation for these two auxin herbicides due to marketing programs. During 2019 and 2020, field and greenhouse studies were conducted to determine which postemergence herbicide was the most effective on tall waterhemp and Palmer amaranth plants surviving a simulated failed application of 2,4-D or dicamba. The second objective was to determine how many days the respray should be delayed to obtain the greatest efficacy. When 2,4-D was the initial herbicide sprayed on waterhemp, field studies showed greater efficacy with fomesafen and glufosinate at the earliest respray timing (7 days after the initial application) when compared to a delayed dicamba application (21 days after the initial application). Greater efficacy with fomesafen and glufosinate was also achieved on Palmer amaranth surviving a 2,4-D application compared to a respray with either 2,4-D or dicamba made at any timing. Also, earlier resprays provided greater control for any given herbicide. When dicamba was the initial herbicide sprayed on waterhemp, field studies showed greater efficacy with fomesafen and glufosinate at the earliest respray timing (7 days after the initial application) compared to a delayed dicamba or 2,4-D application (21 days after the initial application). Additionally, when dicamba was the initial herbicide sprayed on Palmer amaranth, fomesafen and glufosinate sprayed 7 days after the failed application reduced biomass by 92% and 2,4-D or dicamba at any respray timing reduced biomass only by 30%. Greenhouse studies comparing the same respray alternatives applied 14 days after the initial application showed that fomesafen rendered a higher level of efficacy than dicamba regardless of whether dicamba or 2,4-D was sprayed first. The timing of the sequential herbicide application proved to be an important factor affecting weed control, explaining the need for early resprays as soon as failure is detected (within 14 days). This research suggests that two consecutive applications of an auxin herbicide may not be the best option for control of failed applications, in addition to being a less desirable approach for resistance management.

Effect of POST Applied Dicamba and Glufosinate Alone or in Sequential Combination on Glyphosate-Resistant Palmer Amaranth in XtendFlex Soybean. Rui Liu*[1], Vipan Kumar[1], Monica Marrs[2], Taylor Lambert[1]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Manhattan, KS (22)

Glyphosate/dicamba/glufosinate-resistant (GDG-R) soybean (XtendFlex®) is a triple-stacked trait technology that allows growers to use POST applications of dicamba and glufosinate for in-season control of glyphosate-resistant (GR) weeds. A field study was conducted at Kansas State University Agricultural Research Center (KSU-ARC) near Hays, KS, to determine the effectiveness of POST applied dicamba and glufosinate alone or in combination and sequential applications for the control of GR Palmer amaranth in GDG-R soybean. A GDG-R soybean variety 'AG37XF1' was planted on June 5, 2021. The study site had a natural infestation of GR Palmer amaranth. Study was established in a randomized complete block design with 4 replications. Treatments included glyphosate at 1260 g ha^{-1}, dicamba at 560 g ha^{-1}, and glufosinate at 657 g ha^{-1} applied alone or in combinations at early post-emergence (EPOST), or in sequential applications at EPOST followed by (*fb*) a late post-emergence (LPOST). All dicamba containing treatments were applied using TTI nozzles, whereas the AIXR nozzles were used for glyphosate and glufosinate treatments. Data on soybean injury (%) and GR Palmer amaranth control (%) at 7, 10, 30, and 80 days after LPOST treatment (DAT) were recorded. At soybean maturity, the aboveground biomass of GR Palmer amaranth was collected using a 1 m^2 quadrat placed at the center of each plot. Soybean yield was also determined at harvest. Results indicated that EPOST applications of dicamba or glufosinate *fb* a LPOST application of glufosinate provided excellent control (98%) of GR Palmer amaranth compared to EPOST treatment of dicamba or glufosinate alone at 30 DAT. GR Palmer amaranth control with tank-mixture treatment of dicamba and glufosinate applied EPOST was also excellent (98%). All treatments provided >80% control throughout the season, except for glyphosate (59 to 78%). Consistent with percent visual control, all tested treatments reduced GR Palmer amaranth biomass significantly (0 to 96 g m^{-2}) compared to nontreated check (178 g m^{-2}). Soybean yield for majority of the tested treatments were significantly higher (ranging from 1872 to 2243 kg ha^{-1}), compared to nontreated check (1547 kg ha^{-1}). Results from this study suggested that tank-mixture of dicamba and glufosinate is more effective compared to EPOST dicamba alone. Adding a sequential LPOST of glufosinate significantly improved control of GR Palmer amaranth compared with EPOST glufosinate alone.

Weed Management in Soybean Using a Combination of Metobromuron and S-metolachlor.
Eric Y. Yu*, Debalin Sarangi; University of Minnesota, St. Paul, MN (23)

Metobromuron is a preemergence residual herbicide that belongs to the chemical group of phenylureas. This herbicide can control selective broadleaves and grass weeds, but it is currently not labeled for use in soybean in the USA. Two experiments were conducted in 2021 at the University of Minnesota Outreach, Research and Education (UMore) Park, located in Rosemount, MN. The first experiment was designed to compare the weed control efficacy and crop safety of metobromuron applied alone or in a tank-mix with metribuzin with other commonly used PRE herbicides in soybean. The second experiment evaluated the weed control efficacy and interaction of metobromuron and *S*-metolachlor when tank-mixed at different ratios. Less than 5% soybean injury was observed with the metobromuron treatments. At 21 days after treatment (DAT), metobromuron showed 87 to 96% control of common lambsquarters (*Chenopodium album*), but woolly cupgrass (*Eriochloa villosa*) control was = 10% at that time. However, combination of metribuzin and metobromuron showed 98 and 94% control of common lambsquarters and woolly cupgrass, respectively, and that was comparable to the weed control with metribuzin alone. Tank-mixing metobromuron with *S*-metolachlor didn't show any antagonistic or synergistic effects. At 21 DAT, metobromuron plus *S*-metolachlor treatments provided 94% control of common ragweed (*Ambrosia artemisiifolia*), which was better than the control obtained with *S*-metolachlor alone (45%). Similar to the first experiment, woolly cupgrass control improved when metobromuron was tank-mixed with *S*-metolachlor. Therefore, results of this research showed that tank-mixing either metribuzin or *S*-metolachlor with metobromuron is needed for broad-spectrum weed control.

Using an Agar-Based Bioassay to Characterize the Interaction Between Mesotrione and Metribuzin on Giant Ragweed. Benjamin C. Westrich*, Bryan G. Young; Purdue University, West Lafayette, IN (24)

Soybean varieties resistant to certain HPPD-inhibiting herbicides, including mesotrione, have recently entered commercial markets. To increase overall weed control and reduce selection pressure for weed resistance, growers planting these soybean varieties may apply mesotrione (pending registration approval) in combination with other herbicide modes of action. Synergistic interactions are often observed when HPPD inhibitors and photosystem II inhibitors are applied together. This study sought to evaluate the interaction of mesotrione and metribuzin (a photosystem II inhibitor) when applied as a mixture for soil-residual control of giant ragweed (*Ambrosia trifida* L.). To isolate the interaction of the herbicide combinations from the variability of the soil matrix, an agar-based bioassay was developed to maintain equally accessible concentrations of both herbicides throughout the entire duration of the experiment. Individual giant ragweed seeds were planted in 15-ml glass culture tubes containing a mixture of agar and herbicide and were placed in a growth chamber. After 14 days, giant ragweed plants were extracted from the agar and imaged using a printer scanner for analysis in ImageJ. Growth reduction as a function of herbicide dose was calculated based on a reduction in both root and shoot area. Dose-response curves were generated using the drc package in R to determine the relative potency of each herbicide applied alone. Then, additional curves were produced for the combination of mesotrione and metribuzin at 1:1, 1:2, and 2:1 ratios of the ED50 values of each herbicide. Analysis with the Isobole method indicated that the 1:1 ratio was clearly synergistic, as the 95% confidence limit of the ED50 fell below the line of independent action. The concave shape of the Isobolograms for the other ratios implied that synergy could occur at these ratios as well. The magnitude of synergy or antagonism observed in the Isobole plots can be precisely defined by an interaction index that quantifies the change in potency when two herbicides are applied as a mixture. The interaction indices were 0.57, 0.69, and 0.71 for the 1:1, 1:2, and 2:1 ratios, respectively, with the upper 95% confidence limit for all estimates being less than 1. This supported our visual assessment of the Isobolograms, as an interaction index less than 1 is considered to be synergistic. Overall, these results indicate that the application of a mixture of mesotrione and metribuzin for soil-residual control of giant ragweed is likely to be synergistic. A similar experiment will be conducted utilizing field soil, rather than agar, to test for a similar interaction under conditions that more closely resemble a production environment.

Competitiveness of an Oat Companion Crop on *Amaranthus spp.* and Soybean. Jeffery K. Stith*, Joseph T. Ikley; North Dakota State University, Fargo, ND (25)

Iron deficiency chlorosis (IDC) and glyphosate-resistant waterhemp (*Amaranthus tuberculatus*) pose challenges to North Dakota soybean growers. Small-grain companion crops have been used with conventionally tilled soybean to alleviate IDC symptoms, yet little information is available about the capability of weed suppression capability of small grains planted simultaneously with soybean. Two field trials were conducted in 2020 and 2021 in Cass County, North Dakota to evaluate the effects of oat companion crop terminated at different timings, and if they would influence IDC symptoms in soybean, *Amaranthus* species populations, and end of season yield. The experiments were a randomized complete block design, arranged in a split-block of oats compared to no oat companion crop. A postemergence herbicide program consisting of glyphosate plus dicamba (1260 g ae ha^{-1} plus 560 g ae ha^{-1}) was applied at 15, 30, 45, and 60 cm oat height to terminate the companion crop and control weeds present in the plots. At termination, weed biomass was collected. Weed control was visually rated on a scale of 0 to 100% (with 0 representing no control and 100 representing complete plant death), and yield was collected. The oat crop did not influence weed biomass until the latest termination timing at either location. Following herbicide application, glyphosate-resistant waterhemp was controlled 41% more at 15 cm when compared to the 60 cm timing, while there were no differences in control of glyphosate-susceptible Powell amaranth (*Amaranthus powellii*) at any termination timing. The highest yield in 2020 at the site with glyphosate-resistant waterhemp was observed in plots without oats when herbicides were applied at 15 and 30 cm oat height, as well as the plots with oats present at the 30 cm termination timing. All other combinations of presence or absence of oats, and other termination timings resulted in yield loss in 2020. At the site with glyphosate-sensitive weed species, there were no yield differences between plots with oats and plots without oats, and yield loss was only observed when applications were made once oats reached 60 cm in height. Yield data from 2021 will be reported at the meeting. The use of oat as a companion crop in soybean could be a feasible technique to reduce IDC in soybean but may not be a profitable technique due to the potential reduction in yield. Furthermore, the companion crop did not provide suppression of *Amaranthus* species until later termination timings, which also led to a loss in soybean yield. Further research will examine this concept in a program with preemergence herbicide applications in a more integrated approach.

Accentuated Injury in Soybean When Thifensulfuron is Co-applied with Glyphosate. Nader Soltani*, Christy Shropshire, Peter H. Sikkema; University of Guelph, Ridgetown, ON, Canada (26)

Three trials (2 in 2019 and 1 in 2020) were completed at the University of Guelph, Huron Research Station near Exeter, ON to determine if the co-application of thifensulfuron with glyphosate accentuates soybean injury in glyphosate-resistant (GR) soybean. At 1, 2, 4, and 8 WAT, thifensulfuron (6 and 12 g ai ha^{-1} representing the 1X and 2X rate, respectively) applied POST with no adjuvants caused up to 5% soybean injury. The addition of a non-ionic surfactant + UAN to thifensulfuron increased soybean injury to up to 24%. There was no decrease in soybean density, dry biomass, height and yield, except soybean dry biomass which was reduced up to 22% with the addition of adjuvants to thifensulfuron at the 2X rate. Glyphosate (1800 and 3600 g ha^{-1} representing the 1X and 2X rate, respectively) applied POST caused no adverse effect on soybean injury parameters evaluated. The co-application of glyphosate + thifensulfuron at the 1X and 2X rates, without additional adjuvants, caused a synergistic increase in soybean injury at 1, 2, 4 and 8 weeks after treatment (WAT), and a synergistic decrease in dry biomass and height. All other interactions were additive. The co-application of glyphosate + thifensulfuron at the 1X and 2X rates, with additional adjuvants, produced a synergistic increase in injury at 1 (1X and 2X rate), 4 (1X rate) and 8 (1X rate) WAT in soybean. All other interactions were additive.

Sensitivity of Various Market Classes of Dry Beans to Tiafenacil Applied Preemergence.
Nader Soltani*, Christy Shropshire, Peter Sikkema; University of Guelph, Ridgetown, ON, Canada (27)

Tiafenacil is a new non-selective, protoporphyrinogen IX oxidase (PPO) - inhibiting pyrimidinedione herbicide that is under consideration for registration in corn, soybean, wheat, cotton, and other crops to control grass and broadleaf weeds prior to crop emergence. The sensitivity of dry beans to tiafenacil is not known. Four field experiments were completed at Exeter and Ridgetown, ON, Canada during the 2019 and 2020 growing seasons to determine the sensitivity of azuki, kidney, small red, and white beans to tiafenacil applied preemergence (PRE) at 12.5, 25, 50, and 100 g ai ha^{-1}. Tiafenacil at 100 g ai ha^{-1} caused 5% or less injury to azuki, kidney, small red and white beans, and 0-3% injury in azuki bean, 1-5% injury in kidney bean, 1-4% injury in small red bean, and 1-4% injury in white bean. Tiafenacil applied PRE at 12.5, 25, 50, and 100 g ai ha^{-1} caused up to 1, 4, 4, and 5% visible dry bean injury, respectively but caused no negative effect on other growth parameters measured including the final seed yield. Crop injury was generally the greatest with tiafenacil at the 100 g ai ha^{-1} in dry beans. Generally, kidney, small red, and white bean were more sensitive to tiafenacil than azuki bean. Dry bean injury was persistent and increased with time with the greatest injury observed 8 WAE. Tiafenacil applied PRE can be a useful addition to the current weed control strategies for grass and broadleaf weed control suppression, especially GR horseweed and amaranth species prior to bean emergence.

A Multi-state Survey of Waterhemp Populations for Responses to Dicamba and Glufosinate. Taylor Nix*, Travis Winans, Jacob E. Vaughn, Mandy Bish, Kevin W. Bradley; University of Missouri, Columbia, MO (28)

Glufosinate and dicamba are commonly utilized for post-emergent control of waterhemp (*Amaranthus tuberculatus*) in current soybean production systems. In recent years there have been multiple instances where glufosinate or dicamba applications have resulted in a lack of complete waterhemp control. To proactively address concerns of potential resistance to these herbicides, waterhemp populations were collected from soybean fields in 2018, 2019, and 2020. Each population was characterized for its ability to withstand applications of glufosinate or dicamba. Over three years, 323 populations from 8 states have been surveyed. Glufosinate was applied at 289 g a.i. ha^{-1} and 594 g a.i. ha^{-1} while dicamba was applied at 560 g a.e. ha^{-1} and 1120 g a.e. ha^{-1}. All applications were made to seedlings 10 cm in height. Visual injury ratings and survival counts were taken 21 days after application. Approximately 10% of plants survived the lower rate of glufosinate in 2020, compared to 20% and 25% survival for populations collected in 2018 and 2019, respectively. Waterhemp survival following application of the higher glufosinate rate has resulted in less than 10% survival each year with 7% in 2018, 3% in 2019, and 5% in 2020. Waterhemp survival following application of the lower rate of dicamba was 28% in 2018 and 2019, and 18% in 2020. Following the higher rate of dicamba, waterhemp survival has been 8, 6, and 8% in 2018, 2019, and 2020, respectively. Results from this survey provide a greater understanding of the potential frequency and distribution of waterhemp resistance to dicamba and glufosinate. This research will continue with waterhemp populations collected in 2021.

Evaluation of Weed Control in Early Planted Soybeans in Kentucky. Catlin M. Young*, Travis Legleiter; University of Kentucky, Princeton, KY (29)

Kentucky farmers are pushing soybean planting dates earlier into the growing season in an effort to increase soybean yield potential. Although this trend itself can be problematic with unpredictable early spring weather conditions, it can also present challenges for proper weed control. The objective of this study was to evaluate the influence of soybean planting date and herbicide program on waterhemp (*Amaranthus tuberculatus* (Moq.) J.D. Sauer) control. No-till soybean were planted at two timings: early March (Ultra-Early) and April (Early). Herbicide programs included combinations of fall burndowns and spring burndowns with and without soil residual herbicides. Evaluations included *A. tuberculatus* densities taken in the fall, at planting, at postemergence (POST) application and 21 days after POST application. Herbicide programs that included a fall burndown resulted in greater *A.tuberculatus* densities at the April planting date as compared to treatments without a fall burndown application. Furthermore, treatments that received a fall burndown resulted in greater *A.tuberculatus* densities 21 days after the POST application, regardless of the planting date. The use of residual herbicides at soybean planting did not reduce *A.tuberculatus* densities at the time of the POST for either planting date. In conclusion of result from this study, fall burndown applications had a greater influence on *A.tuberculatus* densities than the presence or absence of residual herbicides applied at planting. This research will be expanded to additional planting dates and herbicide programs in 2022 and 2023.

Influence of Different 2,4-D Formulations and Tank Mix Partners on 2,4-D Volatility.
Matthew Osterholt*[1], Daniel B. Reynolds[2], Jason K. Norsworthy[3], Mandy Bish[4], Kevin W. Bradley[4], Bryan G. Young[1]; [1]Purdue University, West Lafayette, IN, [2]Mississippi State University, Mississippi State, MS, [3]University of Arkansas, Fayetteville, AR, [4]University of Missouri, Columbia, MO (30)

Since the introduction of 2,4-D-resistant crops, off target-movement of 2,4-D to other sensitive crop species has been a concern. While previous research has indicated that the choline formulation of 2,4-D is less volatile than the ester and amine formulations, little research has been conducted on the volatility of 2,4-D choline when applied with other post-emergence herbicides and adjuvants. As a result, a low-tunnel experiment was conducted to evaluate the impact of applying different formulations of 2,4-D with glyphosate, glufosinate, and/or ammonium sulfate (AMS) on 2,4-D volatility. The experiment was conducted in 2020 and 2021 by Mississippi State University and Purdue University with the University of Missouri and University of Nebraska conducting the experiment in 2020. The treatments were: 1) the dimethylamine salt of 2,4-D and potassium salt of glyphosate 2) 2,4-D choline 3) 2,4-D choline, glyphosate, and AMS 4) 2,4-D, glufosinate, and AMS 5) a premix of 2,4-D choline and glyphosate 6) a premix of 2,4-D choline and glyphosate along with AMS, and 7) non-treated check. The herbicide rates for 2,4-D, glyphosate, and glufosinate that were 4260, 5043, and 2622 g ae ha^{-1}, respectively, which represents a 4X increase from the typical field use rate. The spray solutions were applied to flats of field soil at a remote location and introduced to the low tunnels thereafter. The treated flats were then placed in the middle of a 15m-long plot that consisted of two rows of 2,4-D-sensitive cotton (*Gossypium hirsutum* L.) planted 76 cm apart. A high volume air sampler was also placed over the treated flats. A plastic sheet was drawn over a tunnel structure covering the flats and the middle 6m of the plot. At 48 hours after the introduction of the treated flats, the tunnels were taken down and the flats discarded. Visual cotton injury and height were recorded at 14 and 28 days after treatment (DAT) in 0.3m increments from the center to the end of the most injured quadrant for each plot. The data from the University of Nebraska is not represented due to a site-year interaction occurring when combined with the other site-years. When the premix of 2,4-D choline and glyphosate was applied with AMS and when 2,4-D choline was applied with glufosinate and AMS, cotton injury was higher at 12 and 15%, respectively next to the treated flats in comparison to the other treatments (3-7%) at 28 DAT. Similarly, the aforementioned treatments resulted in cotton injury 3m from the treated flats, which was greater than all the other treatments where injury traveled up to 1.5m. Cotton height next to the treated flats was similar for all treatments at 14 or 28 DAT. These results indicate that applying AMS with the pre-packaged mixture of 2,4-D and glyphosate increases 2,4-D volatility. Additionally, 2,4-D volatility increased when glufosinate and AMS was applied with 2,4-D choline. Overall, this research indicates that 2,4-D volatility and movement is less than dicamba when tested under similar experimental conditions and when soybean as the sensitive crop.

Examining the Influences of Delayed Activation and Cover Crop Residue on the Efficacy of Acetochlor. Bradley J. Decker*, Eric J. Miller, Karla L. Gage; Southern Illinois University, Carbondale, IL (31)

The climate change prediction scenarios for southern Illinois suggest variable growing seasons with the potential for extended periods of summer drought. As site of action group 15 herbicides rely on rainfall for activation, changes in environmental factors can impact the efficacy of these herbicides. Group 15 soil residual herbicides such as acetochlor are very important in providing overlapping residual weed control in both corn and soybean production, and with herbicide resistance developing so rapidly, the need for effective residual herbicides is crucial to minimize dependency on postemergence herbicides. With cover crops regaining popularity in production agriculture, there is a need to examine the potential impacts of cover crop residue on the efficacy of soil residual herbicides. The objective of this study is to examine the influences of delayed activation and cover crop residue on the efficacy of acetochlor. This study was conducted in 2021 at the Tree Improvement Center greenhouse in Carbondale, Illinois. Pots consisted of a bottom layer of 6 inches of 1:1:1 mixture of topsoil, sand, and potting soil to allow for root aeration and to prevent shrinking and swelling of soil after irrigating, with 2 inches of topsoil added to the surface to mimic field soil. All pots were seeded with 0.3 grams of common waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer). Cereal rye biomass was placed on the soil surface in half of the pots by assigned treatment at 27.7 g pot^{-1}, which represents the field biomass rate of 3807.5 kg ha^{-1}. All treated pots were sprayed with 1261 g ai ha^{-1} of acetochlor (Warrant). Then 1.27cm of simulated rainfall was applied to pots at activation timings of 0, 7, 14, 21, 28, 56, and 112 days after application, and misted to maintain moisture in the germination zone after activation. Data collection consisted of weekly waterhemp counts and visual ratings. Final counts and ratings as well as common waterhemp and remaining cereal rye biomass were taken at 56 days after activation. A two-way ANOVA showed highly significant differences in activation timing as well as a highly significant cover crop x activation timing interaction on visual ratings of common waterhemp control. The data suggest that without cereal rye biomass, acetochlor loses efficacy at 28 days after application without activation; cereal rye residue seemed to negatively impact the efficacy of acetochlor when compared to the non-cover crop residue pots until 21 days after application. Beyond 21 days without activation, cereal rye seemed to have the inverse effect and slow the breakdown of acetochlor, with 28 and 56 days after application showing significantly greater control in the presence of cereal rye biomass. Final count data shows that cover crop residue reduced the number of waterhemp plants in the pots. Cover crop residue, though, significantly increased the average heights of common waterhemp in the treated pots and significantly increased the end-of-season dry weights. Overall, these data suggest a complex relationship between the effects of cover crop residue and delayed activation of acetochlor.

Comparison of Banded vs Blanket Preemergent Herbicide Applications in a Cereal Rye Cover Crop. Alexander R. Mueth*, Eric J. Miller, Karla L. Gage; Southern Illinois University, Carbondale, IL (32)

When planted as a cover crop, cereal rye (*Secale cereale* L.) may provide several long term benefits, including reduction of soil erosion, accumulation of organic matter, and suppression of winter and summer annual weeds. Cereal rye has been shown to reduce the emergence and growth of small seeded broadleaf weeds, such as waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer), especially between crop rows, where there is less disturbance of cover crop residue during planting. Banded applications of herbicide may allow a reduction in the total amount of herbicide applied to the field, while taking advantage of the ability of cover crop biomass to suppress weeds between the rows. Therefore, the objective of this research is to evaluate a banded pre-emergence herbicide program for weed control efficacy, compared to a traditional broadcast pre-emergence program in cereal rye plus balansa clover (*Trifolium michelianum* Savi ssp. *balansae* (Boiss.) Ponert) cover crop. In the fall of 2020, a cereal rye and balansa clover cover crop mixture was planted at 100.9 and 6.7 kg ha-1, respectively. In 2021 Enlist E3 soybeans were planted into the cover crop mixture at 444,789 seeds ha^{-1} on 76.2 cm rows using a roller-crimper planter. The planter removed cover crop biomass from a roughly 25 cm area directly over each row creating a 30% thicker mat of biomass in the interrow space while leaving bare ground in the crop row furrow. Pre-emergent herbicide treatments of flumioxazin and chlorimuron-ethyl at 84 and 29.9 g ai ha^{-1} broadcast, or 30.9 and 10.6 g ai ha^{-1} banded were applied across 3 x 12 m plots in a split-plot trial. Post-emergent applications of glyphosate and 2,4-D at 1270 and 1060 g ai ha^{-1} or acetochlor, glyphosate and 2,4-D at 1266.6, 1270 and 1060 g ai ha^{-1} were made at 10 to 15 cm weed height. There were no statistical differences in waterhemp or marestail (*Conyza canadensis* (L.) Cronquist var. *canadensis*) suppression between banded and broadcast pre-emergent herbicide applications. This study suggests that weed control and yield may be comparable between banded and broadcast pre-emergence applications, with a 65% reduction in herbicide usage in the banded treatments.

Effect of Postemergence Herbicide Application Timing and Sequence on Weed Control in Enlist E3 Soybean. Navjot Singh*[1], Ryan P. Miller[1], Thomas J. Peters[2], Seth L. Naeve[1], Debalin Sarangi[1]; [1]University of Minnesota, St. Paul, MN, [2]North Dakota State University, Fargo, ND (33)

Introduction of multiple herbicide-resistant soybean is providing an opportunity to apply some of the POST herbicides that are considered lethal to non-genetically engineered soybean. The Enlist E3 soybean (resistant to 2,4-D choline, glyphosate, and glufosinate) is widely adopted by the growers in Minnesota to control glyphosate-resistant weeds, and the importance of early-season weed management in soybean is well-documented. To minimize soybean yield losses, assessment of optimum timing and sequence for POST herbicide applications is important. The objective of this research was to compare waterhemp [*Amaranthus tuberculatus* (Moq.) J. D. Sauer] and common lambsquarters (*Chenopodium album* L.) control and soybean yield with different POST application timing and sequence in Enlist E3 soybean. Field experiments were conducted at Rosemount, MN, in 2021, and the treatments included early-, mid-, and late-POST applications of 2,4-D choline, glyphosate, and glufosinate, and their combinations along with a PRE (acetochlor) or no-PRE. Averaged across the treatments, acetochlor applied as PRE provided 97% waterhemp control and reduced density to 2 plants m^{-2} compared with 240 plants m^{-2} in nontreated control at 21 days after treatment (21 DAT). The PRE fb POST programs resulted in 98% waterhemp control and = 2 plants m^{-2} density at 28 days after late-POST (DALP), whereas, POST-only herbicide programs had 91% waterhemp control and a density of 15 plants m^{-2} at that time. Glufosinate applied one-time either after PRE or no-PRE provided = 38% control of common lambsquarters at 28 DALP. The results of this research showed that an application of PRE herbicide was important for waterhemp control, and the POST-only treatments of glufosinate were not sufficient for season-long weed control in Enlist E3 soybean.
Keywords: Glufosinate, herbicide sequence, multiple herbicide-resistant, PRE followed by POST, resistance management

Residual Control of Giant Ragweed with Preemergence Soybean Herbicides. Ryan P. DeWerff*, Nicholas J. Arneson, Maxwel Coura Oliveira, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (34)

Giant ragweed (*Ambrosia trifida*) is a troublesome weed species in Wisconsin soybean production. Extended emergence window, aggressive growth, and resistance to ALS- and EPSPS-inhibitor herbicides have resulted in increased grower reliance on preemergence (PRE) herbicides for giant ragweed control. The objective of this study was to investigate the efficacy of commonly applied PRE soybean herbicides on giant ragweed control. Soybean trials were established near Janesville, WI (Silt loam soil, pH=6.7 and 3.3% OM; giant ragweed as the predominant weed species) in the spring of 2019, 2020, and 2021 in a RCBD with four replications (3 x 7.6 m plot size). Soybeans were established on 12 May 2019 (variety: AG21X7), 12 May 2020 (variety: AG21X7), and 24 April 2021 (P20T64E) at 385,000 seeds ha^{-1}. Prior to trial establishment, fields were in a corn-soybean crop rotation and were fall chisel-plowed and spring cultivated. Herbicide treatments consisted of single site of action (SOA) and multiple SOA premix combination products. Herbicide rates were based on soil characteristics and label requirements. Herbicides were applied within three days of soybean planting with a CO_2 -pressurized backpack sprayer delivering 140 L ha^{-1} of spray solution using TTI 110015 nozzles. No POST herbicides were applied to the study. At ~25 and 50 days after treatment (DAT), visual herbicide efficacy data were collected. At ~50 days after treatment, weed biomass was sampled and forced air dried at 60° C until constant dry weigh. ANOVA was performed for dry biomass (g) and giant ragweed control (%); herbicide treatments and year were treated as fixed effects whereas replication was treated as random effect. In 2019 at 22 DAT, chlorimuron-ethyl + metribuzin + flumioxazin, chlorimuron-ethyl + flumioxazin + pyroxasulfone, chlorimuron-ethyl + flumioxazin, and cloransulam-methyl + sulfentrazone all provided > 90% control. In 2020 at 22 DAT, no herbicide provided > 90% control; however, cloransulam-methyl + sulfentrazone, cloransulam-methyl + flumioxazin, fomesafen + S-metolachlor, chlorimuron-ethyl + flumioxazin + pyroxasulfone, and chlorimuron-ethyl + flumioxazin provided > 80% control. No herbicides provided adequate control of giant ragweed ~50 DAT in 2019 or 2020 (control <70% for all treatments). Highest control efficacy was achieved with combination of herbicide groups 2+14 and/or 15 sprayed at appropriate rates. Weed biomass and 2021 efficacy data are still being processed and analyzed. This trial showcases the efficacy of several PRE soybean herbicides for giant ragweed control and can support product selection decision by soybean growers.

Planting Green in Soybean: Evaluation of Cereal Rye Termination, Weed Control, and Soybean Yield. Trey P. Stephens*[1], Jenny Rees[1], Stevan Knezevic[2], Humberto Blanco[1], Katja Koehler-Cole[1], Amit J. Jhala[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska Lincoln, Concord, NE (35)

The introduction of cover crops began in the 19th century and the adoption of cover crops has increased tremendously in the past two decades. A conventional practice of cover crop establishment is during fallow periods in the winter in the Midwestern United States. Terminating the cover crop is an integral part of cover crop rotations with cash crops. The general practice is to terminate the cover crop prior to planting the succeeding cash crop. Planting green is a different approach that allows producers to plant cash crops into an actively growing cover crop and terminate after the establishment of a said cash crop. This allows for higher production of biomass and weed suppression further into the growing season. A field study was conducted at South Central Ag Lab, University of Nebraska, Clay center, NE to determine the effect of planting green on weed suppression and soybean yield. This study has two factorials: termination timing and herbicide application timing. Termination timings were: two weeks before planting (2WBP) and two weeks after planting (2WAP) of soybean. Herbicide application timings were: PRE, early POST, and PRE followed by (fb) late POST. Terminating cereal rye 2 WAP provided better weed suppression and reduced weed density compared with terminating 2 WBP. Herbicides applied PRE provided 90%-99% control of Palmer amaranth (*Amaranthus palmeri*), velvetleaf (*Abutilon theophrasti*), common lambsquarters (*Chenopodium album*), and foxtail *Poaceae* species. Frequent rain in the month of May after soybean planting and PRE herbicides applied provided excellent moisture for herbicide activation. Most PRE followed by POST herbicides provided >90% weed control and reduced Palmer amaranth seed production. A combination of planting soybean when cereal rye is green and applying a PRE herbicide and a follow up POST herbicide can provide better early and late season weed control in soybean.

The Use of UAVs for Crop Protection. Emma L. Gaither*, Reid Smeda; University of Missouri, Columbia, MO (36)

Unmanned aerial vehicles (UAVs) with spraying capabilities can improve application efficiency in conditions challenging for traditional, ground-based spray equipment. UAVs can spray over tall vegetation and the rotor wash can potentially penetrate dense plant canopies. To observe coverage patterns using UAV technology, sodium chlorate was applied aerially on VT corn (*Zea* mays) at 37.4 (low), 74.8 (medium), or 149.6 (high) $L \cdot ha^{-1}$ spray volumes and compared to a ground application at 149.6 $L \cdot ha^{-1}$. Seven days after treatment (DAT) defoliation was rated visually on a scale of 0-100 above and below ear leaf. UAV coverage at the medium spray volume was comparable to a ground application at the high spray volume with approximately 42 and 41% defoliation respectively. At the high spray volume, the UAV resulted in the highest defoliation, 55%. Observations of defoliation showed that the UAV resulted in more uniform coverage because of rotor wash. To further visualize these differences, spray sensitive paper was placed level with the ear leaf, the leaf below the ear, and the leaf above the ear and all four treatments were repeated. Results of paper coverage with liquid will be presented to document the effectiveness of UAV applications. Results have important implications for specialized uses where ground-based application is difficult.

Impact of Spray Carrier Volume and Nozzle Selection on Control of Volunteer Corn with Clethodim and Velvetleaf and Waterhemp with Glufosinate. Nikola Arsenijevic*, Felipe de Andrade Faleco, Nicholas J. Arneson, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (37)

Volunteer corn, velvetleaf and waterhemp are common weeds in soybean cropping systems across the US North Central region often treated by growers with POST herbicides at advanced growth stages (>10 cm). The objective of this greenhouse experiment was to evaluate the efficacy of clethodim on corn, and glufosinate on waterhemp and velvetleaf applied with different nozzles (DG09502EVS and AI09502EVS) and carrier volumes (94, 140 and 187 L ha^{-1}). The experiment was conducted in a RCBD, 6 reps per treatment, with two experimental runs. Clethodim (51 g ai ha^{-1} + COC 1% v/v) was applied when corn plants reached 40 cm in height and glufosinate (265 g ai ha^{-1} + 1428 g ha^{-1} AMS) was applied when waterhemp and velvetleaf plants reached 20 cm. Treatments were applied in a single-nozzle spray chamber. In addition, water sensitive spray deposition cards were used to evaluate number of droplets and spray coverage across treatments. At 21 days after treatment (DAT), visual control was collected on a scale from 0 to 10 (0 - 3 = dead plant, >3 = regrowth observed), plants were then harvested and oven dried at 60^{o} C until constant weight. According to the ANOVA results, nozzle selection and carrier volume did not impact biomass of clethodim treated corn and glufosinate treated waterhemp plants. According to visual control results, all corn plants were completely controlled by clethodim but >95% of waterhemp plants survived the glufosinate application across treatments (e.g., presented regrowth 21 DAT). For glufosinate treated velvetleaf plants, AI09502EVS spray nozzle reduced biomass 27% more than DG09502EVS spray nozzle. Velvetleaf plants treated with AI09502EVS spray nozzle were slightly better controlled (visual control = 5.7) compared to DG09502EVS (6.3); overall, all velvetleaf plants survived the glufosinate application. DG09502EVS nozzle produced 35% more droplets when compared to AI09502EVS. As expected, the 187 L ha^{-1} carrier volume treatment had the highest spray card coverage (38.1%) followed by 140 (30.6%) and 94 L ha^{-1} (21.4%); however, carrier volume rate did not impact weed control in this study as we anticipated it would. Applying glufosinate on waterhemp and velvetleaf plants at advanced growth stages (20 cm) resulted in lack of effective control (regrowth observed 21 DAT for most treated plants). For corn (volunteer), effective control was observed even though plants were at an advanced growth stage, regardless of carrier volume rate and nozzle selection. Use of glufosinate as a rescue strategy for broadleaf weed control in soybeans is not a sustainable strategy. Additional research will be conducted evaluating the impact of plant size and glufosinate tank mixes for control of established broadleaf weeds in soybeans.

Application Method and Environmental Impacts on Palmer Amaranth Control with Glufosinate and Paraquat. Jeff Golus*[1], Bruno Canella Vieira[2], Greg Kruger[1], Kasey Schroeder[1], Vinicius Velho[1], Barbara Vukoja[1], Trenton W. Houston[1]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Wisconsin-Madison, Madison, WI (38)

With the increased presence of glyphosate-resistant weeds in row crops and fallow areas, glufosinate and paraquat have become important options for their control. Of concern is the Amaranthus species, particularly Palmer amaranth (*Amaranthus palmeri* S. Watson). Greater efficacy has been achieved when glufosinate is applied in warmer, more humid conditions. However, these conditions become less frequent in the High Plains area of the US. Paraquat efficacy is usually associated with nozzle selection and carrier volume. The objective of this study was to evaluate the effect of environmental conditions and application technique of glufosinate and paraquat on Palmer amaranth control. Field studies were conducted in 2020 and 2021 at the University of Nebraska West Central Research, Extension and Education Center in North Platte, NE. Applications were made over the course of three consecutive days to capture diverse environmental conditions. Temperature, relative humidity, wind speed, photosynthetically active radiation and solar radiation intensity were recorded over the three days. Application methods, including carrier volume, product formulation and droplet size were also evaluated. Palmer amaranth dry biomass was recorded 25 days after treatment, and control percentage was calculated in relation to nontreated control. Data were submitted to a Random Forest analysis using the "randomForest" package in R software. Results from 2020 showed application technique factors such as carrier volume and nozzle selection had less influence on glufosinate control when compared to environmental factors (temperature, humidity and solar radiation levels). Droplet size had greater influence with paraquat applications.

Effectiveness of Glufosinate on Troublesome Warm-Season Weeds as Influenced by Carrier Volume and Ammonium Sulfate. Nina Pejovic*, Milos Zaric, Jesaelen Gizotti de Moraes; University of Nebraska Lincoln, North Platte, NE (39)

Glufosinate herbicide has become a critical tool used in the management of glyphosate-resistant weed species in cotton and other crops. Its performance is greatly influenced by water hardness and ammonium sulfate (AMS) is recommended to improve weed control efficacy. However, glufosinate and AMS doses may vary depending on the postemergence program. Therefore, the objective of this research was to investigate the impact of different doses of glufosinate applied with and without AMS on weed control as influenced by carrier volume. Dose response greenhouse studies were conducted at the Pesticide Application Technology Laboratory using seven doses of glufosinate (6.56, 13.12, 65.6, 131.20, 656, 3280, 6560 g ai ha^{-1}), two doses of AMS (0 and 5% v v^{-1}), and two carrier volumes (93 and 187 l ha^{-1}) applied to green foxtail [*Setaria viridis (*L.) P. Beauv.], signalgrass [*Urochloa platyphylla* (Munro ex C. Wright*)* R.D. Webster] , velvetleaf (*Abutilon theophrasti* Medik), sicklepod [*Senna obtusifolia* (L.) H.S. Irwin & Barneby], common lambsquarters (*Chenopodium album* L.), and waterhemp [*Amaranthus tuberculatus* (Moq.) J.D. Sauer]. A non-treated control was included for a total of 29 treatments. Spray herbicide applications were made using a three-nozzle research sprayer using the AIXR11004 nozzle at 276 kPa at speed of 5.31 m s^{-1} (93 l ha^{-1}) or 2.65 m s^{-1} (187 l ha^{-1}). Plants above ground biomass were harvested at 28 days after application and dried at 65°C to a constant mass. Dry biomass was recorded and converted into percent of biomass reduction. Data were fitted to a non-linear regression model with the drc package in R software. The ED_{50} and ED_{90} values for each weed species were estimated using a for parameter log logistic equation. Overall, the addition of AMS improved glufosinate effectiveness at both carrier volumes but results were herbicide and AMS dose-, carrier volume, and weed species-specific. Depending on the weed species it was observed a plant growth stimulation at the lowest doses of glufosinate.

The Use of Canopeo App for Data Collection in Weed Science. Nikola Arsenijevic*, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (40)

In some instances, the data collection in weed science can be challenging and difficult to replicate due to personal biases. Taking advantage of certain mobile applications can expedite the process and provide more accurate assessments. The Canopeo app (www.canopeoapp.com), developed by scientists at Oklahoma State University, is a tool that can be used to quantify the percent canopy cover of live green based on downward-facing photos taken with a mobile device or camera. The Canopeo app is gaining popularity in weed science due to the numerous ways it can be utilized for data collection. For instance, it has been used to estimate crop development (percent of canopy coverage) over the course of the growing season, herbicide crop injury, weed ground coverage, crop variety vigor, impact of seed treatments, and so forth. The main advantage of Canopeo is its ease of use and rapid result estimation as it requires a smart phone mobile device with camera at the minimum. In addition, if coupled with MatLab, Canopeo app allows for quick processing of high number of photos in a matter of minutes. Mobile phone devices can be connected to the external cameras that can provide different view-finding capabilities, especially when it comes to keeping track of crop and/or weed growth over the growing season. Canopeo results are consistent, however, data collection setup needs to follow certain adjustments to maintain the consistency. Constant height over the course of data collection is crucial, especially if data collection spans over the entire growing season and/or across multiple treatments. Furthermore, recording more photos within the designated experimental area will typically yield better results. The focus of this poster will be to highlight the potential uses and instruct new users about how to use the Canopeo app for weed science data collection. This includes ideas on how to build specific camera mounting equipment, how to effectively maintain the constant height during image collection, as well as to showcase the results of projects evaluating soybean canopy development over the season and evaluation of herbicide injury using Canopeo app for data collection.

A Survey of Kansas Herbicide Applicators to Guide Research and Extension. Lily A. Woitaszewski*, Tyler P. Meyeres, Chad J. Lammers, Sarah Lancaster; Kansas State University, Manhattan, KS (41)

A survey was conducted to evaluate herbicide application practices and determine how to best address the needs of herbicide applicators across Kansas. The survey was distributed electronically during spring 2021. A total of 206 responses were submitted. Of 143 respondents providing information on burndown herbicide applications (BD), 102 were commercial applicators and 41 were private applicators. Fifty percent reported using spray volumes of 10 to 14 gallons per acre (GPA). This accounted for 46% of commercial applicators and 61% of private applicators. Thirty-four percent of commercial applicators used 15 to 19 GPA, while 27% of private applicators used the same spray volume. Twelve percent of commercial applicators and 5% of private applicators used 5 to 9 GPA. When considered by region, 143 responses were recorded with 63 in central Kansas, 37 in eastern, 38 in western, and that 5 didn't provide location. Forty-six percent of respondents from the central region used 15 to 19 GPA for BD. In the western region, 50% used 10 to 14 GPA and 24% used 5 to 9 GPA. There were 140 responses for pre-emergence applications (PRE), with 99 from commercial applicators and 41 from private applicators. Fifty-five and 56 percent of commercial and private applicators, respectively reported using 10 to 14 GPA. Thirty-two percent of commercial applicators and 24% of private applicators reported using15 to 19 GPA for PRE. Sixty respondents were in central Kansas, 37 in both eastern and western, and 5 didn't respond with location. Ten to 14 GPA was reported by 65, 48, and 57% of respondents from eastern, central, and western Kansas, respectively. Twenty-seven and 43% of respondents from eastern and central Kansas, respectively reported using 15 to 19 GPA for PRE, while the 22% of respondents from western Kansas used 5 to 9 GPA. For post-emergence applications (POST), 138 responses were recorded. Of those, 97 responses were commercial applicators and 41 were private applicators. The most frequently reported spray volume was 15 to 19 GPA, which accounted for 45 and 56% of commercial and private applicators, respectively. This change relative to BD and PRE reflects the importance of spray volume for POST efficacy; however, 35 and 29% of commercial and private applicators, respectively, reported using 10 to 14 GPA for POST. Of 138 respondents, 60 were in central Kansas, 36 in western, 37 in east, and 5 locations were not provided. Most applicators from eastern and central Kansas, 57 and 62%, respectively used 15 to 19 GPA, while most applicators (61%) from the western region used 10 to 14 GPA. These responses suggest private applicators in Kansas are likely to use greater spray volumes than custom applicators, and lesser spray volumes are applied in the western portion of the state compared to eastern and central Kansas. These findings suggest a need for applied research and extension activities targeting commercial applicators in western Kansas to reinforce the importance of carrier volume for efficacy of post-emergence herbicides.

Grass Weed Control in Herbicide-Resistant Grain Sorghum. Vipan Kumar*, Rui Liu, Taylor Lambert, Sachin Dhanda, Monica Marrs; Kansas State University, Hays, KS (42)

Lack of over-the-top herbicide (POST) options is a serious challenge for in-season grass weed control in sorghum. Recent development and commercialization of three different sorghum hybrids with tolerance to imazamox (Igrowth™ sorghum), nicosulfuron (Inzen™ sorghum), and quizalofop-p-ethyl (Double Team™ sorghum) will allow growers to use these respective herbicides for in-season control of grass weeds. The main objective of this research was to determine the effectiveness of various herbicide programs (PRE, POST or PRE followed by (fb) POST) for grass weed control in these new herbicide-resistant (HR) sorghum technologies. Three HR grain sorghum hybrids viz. Igrowth™, Double Team™, and Inzen™ were separately planted in field experiments during 2021 growing season at Kansas State University Agricultural Research Center near Hays, KS. The field site had natural infestation of green foxtail (*Setaria viridis* L.). Each field experiment was conducted in a randomized complete block design with 4 replications. For Igrowth™ sorghum, the tested herbicide programs included PRE alone treatments of s-metolachlor (1422 g ha^{-1}), atrazine + s-metolachlor (1519 + 1176 g ha^{-1}), and imazamox (52 and 78 g ha^{-1}); POST alone treatment of imazamox (52 g ha^{-1}); and PRE applied s-metolachlor (1422 g ha^{-1}) fb a POST application of imazamox (52 and/or 78 g ha^{-1}). For Double Team™ sorghum, the tested programs included PRE applied atrazine (1120 g ha^{-1}) fb a POST treatment of quizalofop-p-ethyl (77 g ha^{-1}) alone or in combination with 2,4-D (560 g ha^{-1}) or dicamba (280 g ha^{-1}). For Inzen™ sorghum, the tested programs included PRE applied atrazine (1120 g ha^{-1}) fb POST treatments of nicosulfuron (35 g ha^{-1}) alone or in combination with 2,4-D (560 g ha^{-1}) or dicamba (280 g ha^{-1}); and PRE applied atrazine + s-metolachlor (1519 + 1176 g ha^{-1}) fb a POST treatment of nicosulfuron (35 g ha^{-1}). Data on percent visible control of green foxtail were recorded at biweekly interval throughout the growing season and aboveground shoot biomass was determined at the end-of the season. Among all programs tested in Igrowth™ sorghum, PRE alone treatment of imazamox at 78 g ha^{-1} and PRE applied s-metolachlor fb a POST treatment of imazamox tested at both rates provided an excellent control (85 to 93%) of green foxtail up to 7 weeks after PRE (WAPRE) or 4 weeks after POST (WAPOST), whereas control did not exceed more than 58% with PRE alone treatments of s-metolachlor or s-metolachlor + atrazine. In Double Team™ sorghum, PRE applied atrazine or atrazine + s-metolachlor fb a POST treatment of quizalofop-p-ethyl alone or in combination with dicamba provided 91 to 95% green foxtail control at 7 WAPRE (4 WAPOST). Tank-mixing 2,4-D with quizalofop-p-ethyl had reduced activity on green foxtail (72% control). In Inzen™ sorghum, PRE applied atrazine or atrazine + s-metolachlor fb a POST treatment of nicosulfuron alone or in combination with 2,4-D provided 86 to 90% green foxtail control at 7 WAPRE (4 WAPOST). These results suggest that effective PRE fb POST herbicide options exist that should be adopted for grass weed control in newly developed HR sorghum technologies.

Managing Waterhemp in Soybean on Low Organic Matter and Elevated pH Soils with Residual Herbicides. Daniel H. Smith*[1], Jamie Patton[2], Scott Reuss[3], Maxwel Coura Oliveira[1], Ryan P. DeWerff[1], Nicholas J. Arneson[1], Rodrigo Werle[1], Kolby Grint[1]; [1]University of Wisconsin-Madison, Madison, WI, [2]University of Wisconsin-Madison, Shawno, WI, [3]University of Wisconsin-Madison, Marinette, WI (43)

Waterhemp (*Amaranthus tuberculatus* (Moq.) J. D. Sauer) is a troublesome weed species in soybean production across the US North Central region. An extended emergence window, rapid growth rate, multiple site-of-action (SOA) resistance, and limited postemergence (POST) control options have resulted in an increased reliance on preemergence (PRE) herbicides for waterhemp control in soybean. Herbicide label restrictions for sand and loamy sand soils with low soil organic matter (SOM) and/or high pH challenge herbicide selection and application rates. The objective of this study was to investigate the efficacy of commonly applied PRE herbicides for waterhemp control in soybean grown in sandy soils with low soil organic matter and high pH. The study was established near Navarino, WI (loamy fine sand, pH=7.5 and 2.2% SOM) in the spring of 2021 in a randomized complete block design with four replications (3 x 7.6 m plot size). The trial followed corn and was chisel-plowed and spring cultivated prior to establishment. Soybeans were planted at 345,947 seeds ha^{-1} (variety: Pioneer 22T18) on May 12, 2021. Herbicide treatments consisted of single SOA and multiple SOA premix combination products. Herbicide treatment and rate selection were based on SOM and pH characteristics, groundwater depth application restrictions, and additional label requirements. Herbicides were applied within three days of planting with a CO_2 -pressurized backpack sprayer delivering 140 L ha^{-1} of spray solution using TTI110015 flat-fan nozzles. No POST herbicides were applied to the study. Herbicide treatments included: group 2: imazethapyr, group 5: metribuzin, group 14: flumioxazin, sulfentrazone, and group 15: acetochlor, dimethenamid-P, pyroxasulfone, and *S*-metolachlor. Three commercial premix products were also evaluated: sulfentrazone + imazethapyr, *S*-metolachlor + sulfentrazone, and flumioxazin + pyroxasulfone. Fifty (50) days after treatment (DAT), waterhemp control (%) was assessed, and weed biomass was sampled and forced air dried at 60° C until achieving a constant dry weight. At 50 DAT, the metribuzin, flumioxazin, acetochlor, dimethenamid-P, pyroxasulfone, and *S*-metolachlor treatments provided >90% waterhemp control. This trial demonstrates the effectiveness of limited PRE herbicide options available to control waterhemp in sand and loamy sands soils with low organic matter and elevated soil pH. This information is crucial to help farmers improve waterhemp management under these challenging soil environments.

Weed Control in Herbicide Resistant Grain Sorghum in Kansas. Malynda M. Smith*[1], Patrick Geier[2], Randall S. Currie[2], Sarah Lancaster[1]; [1]Kansas State University, Manhattan, KS, [2]Kansas State University, Garden City, KS (44)

Herbicide-resistant grain sorghum technologies for enhanced control of grass species require new recommendations for weed control using these systems to enable producers to choose the best technology for their operation and to maximize weed control within their chosen system. The primary objective of this trial was to compare weed control efficacy among imazamox-, quizalofop-, and nicosulfuron-resistant grain sorghum varieties. Experiments were conducted near Manhattan and Garden City, Kansas during 2021. Weed control was visually assessed 4 weeks after post-emergence (POST) applications. Primary weed species evaluated were large crabgrass (*Digitaria sanguinalis* (L.) Scop.) and Palmer amaranth (*Amaranthus palmeri* S. Watson) at Manhattan and green foxtail (*Setaria viridis* (L.)) and large crabgrass at Garden City. Means were separated using LSD (a = 0.05). At Manhattan, Palmer amaranth control was ≥ 98% in treatments with *S*-metolachlor (1423 g ai ha^{-1}) or s-metolachlor + atrazine (1177 g ai ha^{-1} + 1513 g ai ha^{-1}) applied PRE. Imazamox (52.68 g ai ha^{-1} or 78.46 g ai ha^{-1}) PRE resulted in 59% Palmer amaranth control. POST application of imazamox + COC (52.68 g ai ha^{-1} + 1% v/v) and imazamox + COC + AMS (52.68 g ai ha^{-1} + 1% v/v + 15% v/v) resulted in 28% and 66% Palmer amaranth control, respectively. Large crabgrass at Manhattan was ≥94% with imazamox PRE (52.68 g ai ha^{-1} or 78.46 g ai ha^{-1}), imazamox POST (52.68 g ai ha^{-1}) and quizalofop (77.34 g ai ha^{-1}) or nicosulfuron (35.19 g ai ha^{-1}) POST, but control was less (91%) with nicosulfuron + dicamba (280.21 g ae ha^{-1}) POST. In Garden City, large crabgrass and green foxtail control was similar (98-100%) with *S*-metolachlor and *S*-metolachlor + atrazine PRE and *S*-metolachlor + imazamox PRE or POST. Imazamox + COC POST resulted in less green foxtail (85%) and large crabgrass (88%) control. The addition of AMS to that treatment resulted in 93% control of green foxtail and 80% control of large crabgrass. Quizalofop or nicosulfuron POST resulted in similar control of green foxtail and large crabgrass (93-100%). Quizalofop + 2,4-D (560.41 g ae ha^{-1}) POST and quizalofop + dicamba (280.21 g ae ha^{-1}) POST resulted in 90% control of green foxtail and in 90 and 80% control of large crabgrass respectively. Nicosulfuron + dicamba POST resulted in large crabgrass control of 83-88%. Overall, large crabgrass and green foxtail control was not increased by the addition of imazamox, quizalofop, or nicosulfuron POST when *S*-metolachlor or *S*-metolachlor + atrazine were applied PRE. Imazamox provided acceptable control of large crabgrass and green foxtail when applied PRE but did not control ALS-resistant Palmer amaranth. Future research should investigate crop response and economics of herbicide-resistant grain sorghum technologies compared to PRE applications of *S*-metolachlor and atrazine alone.

There and Back Again: A Look at North Dakota Weed Control Research Over 50 Years.
Stephanie DeSimini*, Joseph T. Ikley, Kirk A. Howatt; North Dakota State University, Fargo, ND (45)

Problematic weed species since the 1970's have changed with the introduction of transgenic crops, new herbicides, new crops, better weed management programs, and climatic shifts. To examine the changes of target weed species in agronomic weed control in North Dakota, we extracted information from a database of herbicide efficacy trials over 50 years. Out of 6,697 trials that were extracted from the database, the most commonly evaluated weed species included: yellow foxtail (*Setaria pumila)*, wild mustard (*Sinapis arvensis* L.), wild oat (*Avena fatua* L.*),* redroot pigweed (*Amaranthus retroflexus*), wild buckwheat *(Fallopia convolvulus* L.), and common lambsquarters (*Chenopodium album* L.). Those six species were consistently ranked in the top 10 throughout the 50-year span. The top 10 most prevalent weeds from 1970 to 2010 included false chamomile (*Matricaria perforata*), Canada thistle (*Cirsium arvense* L.) leafy spurge (*Euphorbia esula* L.), and kochia (*Bassia scoparia* L.). Those weeds were replaced by Venice mallow (*Hibiscus trionum* L.), common cocklebur *(Xanthium strumarium* L.), waterhemp (*Amaranthus tuberculatus*) and common ragweed (*Ambrosia artemisiifolia* L.) from 2011 to 2020. The most evaluated weed species from 1970 to 2011 was yellow foxtail, with 62% of trials containing yellow foxtail at evaluation. From 2011 to 2020 however, common lambsquarters was the most prevalent, found in 42% of total trials conducted. While wild mustard was the 2nd most prevalent weed from 1970 to 1989, being found in 35% of trials, it dropped to 14% from 2011 to 2020. Waterhemp was not recorded in the top 10 weeds until 2011 to 2020, where it was found in over 22% of all studies across the state, an increase from <1% prevalence in previous years. These results reflect that target weed species and research foci across North Dakota have changed over time, and will continue to change as weather, transgenic crops, changes in crop demands, and herbicide resistance continue to put pressure on our ability to control weeds.

Farmer Survey Reveals New Trends in Weed Management. Lizabeth Stahl*[1], Jared J. Goplen[2], Anthony A. Hanson[2], Ryan P. Miller[3], David Nicolai[4], Angie J. Peltier[5]; [1]University of Minnesota Extension, Worthington, MN, [2]University of Minnesota Extension, Morris, MN, [3]University of Minnesota, Rochester, MN, [4]University of Minnesota Extension, Farmington, MN, [5]University of Minnesota Extension, Crookston, MN (46)

Since 2003, farmers attending private pesticide applicator recertification (PAR) workshops in Minnesota have been asked about the pest management issues they face and strategies they are using or planning to use through an Integrated Pest Management (IPM) Assessment. Turning Technologies, LLC ResponseCards have been used in recent years to collect response data, although in 2021, a switch to online delivery due to COVID-19 resulted in the collection of polling date through Zoom and Qualtrics. PAR is on a three-year cycle in Minnesota, so the group surveyed every three years is similar. Herbicide-resistant weeds continue to be a challenge. Averaged over five years (2017 to 2021), resistance to glyphosate was most-commonly reported (76% of respondents), compared to resistance to PPO- and ALS-inhibitors (16 and 15% of respondents, respectively), although the prevalence of these issues is likely higher, particularly for ALS-resistance. Waterhemp (*Amaranthus tuberculatus*) (67% of respondents) and giant ragweed (*Ambrosia trifida*) (33% of respondents) were reported as the most common herbicide-resistant weeds in 2021. Layering PRE herbicides (e.g. apply a PRE at planting and then 30 days later) can aid in waterhemp management and in 2021, 57% of respondents reported they used this tactic and it worked well, while 16% reported they used it with marginal or limited success. Most farmers planned to plant herbicide-resistant soybeans, with only 7 to 11% of respondents from 2018 to 2021 indicating they planned to plant conventional soybean. Planned use of Enlist E3™ soybeans increased from 4% in 2018 to 52% in 2021, but decreased for Roundup Ready soybeans from 49% in 2018 to 19% in 2021. Planned use of Liberty Link® / Liberty Link® GT27™ soybeans ranged from 16 to 32%, and from 32 to 45% for Roundup Ready 2 Xtend® soybeans over the 2017 to 2021 time period, while 19% of respondents planned to use XtendFlex® soybeans in 2021. Respondents were also asked about their use of non-chemical weed control tactics the previous year. Only 11% of respondents in 2021 indicated they did not use any of the strategies listed, down from a high of 27% in 2019. Use of all the strategies listed increased when comparing results from 2017 to 2021, but to varying degrees. This included rotating herbicide-resistant traits (7% in 2017 to 51% in 2021), altering the crop rotation planned (21% in 2017 to 38% in 2021), using mechanical weed control (10% in 2017 to 27% in 2021), hand-pulling weeds (24% in 2017 to 32% in 2021), planting cover crops (6% in 2017 to 16% in 2021), harvesting weedy areas separately (5% in 2017 to 10% in 2021) and delaying planting/tillage (5% in 2017 to 8% in 2021). This information has been useful in developing educational programming around the management of herbicide-resistant weeds.

Cereal Rye Tolerance to Weedy Grass Herbicides. Dwight Lingenfelter*, John M. Wallace; Penn State University, University Park, PA (47)

Cereal rye (*Secale cereale* L.) is a commonly used cover crop species and one of the least expensive seed options. Since cereal rye is a useful cover crop species, some farmers are interested in growing rye not only as a winter cover but also to harvest the seed for sowing in subsequent years. Currently, cereal rye has the fewest number of herbicides registered compared to other commonly planted small grains; and furthermore, none have activity on weedy grasses. Therefore, field studies were conducted in 2019, 2020, and 2021 to determine the safety of various small grain herbicides on cereal rye with an emphasis on those that control grassy weeds. Cereal rye (var. 'Aroostook') was planted each year in late September at 67 or 101 kg ha^{-1}. Studies were arranged in a randomized complete block design with three replications. Herbicides were applied with a small-plot, CO_2-backpack sprayer system that delivered 140 L ha^{-1} thru TeeJet AIXR110015 nozzles. Treatments were applied to the rye in the fall (2-leaf stage; 5-10 cm tall) and in the spring (23-33 cm tall). Treatments included: flufenacet + metribuzin (381 g ai ha^{-1}), pendimethalin (1064 g), pyroxasulfone (119 g), metribuzin (157 g), mesosulfuron (15 g), pyroxsulam (18 g), halauxifen + florasulam (11 g), thifensulfuron + tribenuron (26 g), chlorsulfuron + metsulfuron (21 g, 2020 and 2021 studies). All herbicides were applied in the fall and spring except for flufenacet + metribuzin, pendimethalin, and pyroxasulfone which were only fall-applied. Appropriate adjuvants were included where necessary. Visual crop injury ratings were collected. Results across all studies for visual crop injury data from either application timing indicate that all herbicides on average cause no more than 5% injury, except metribuzin (14-35 % injury) and mesosulfuron (13-57% injury). Mesosulfuron showed the highest level of injury when applied either in the fall or spring, however, rye was injured most when applied during the early stages of growth. Metribuzin and flufenacet + metribuzin showed variable injury (2-35%), however more injury was observed from the fall application. In summary, the results of these crop safety studies of herbicides currently not labeled for use on cereal rye show there is potential for some to receive registration for this crop. Especially those that provide control of weedy grass species such as pyroxsulam and thifensulfuron + tribenuron, a frequently used premix in other small grains, for control of many broadleaf weeds.

History of Weed Management in Minnesota and North Dakota. David Nicolai*[1], Thomas Peters[2], Roger Becker[1], Calvin Messersmith[2]; [1]University of Minnesota, St. Paul, MN, [2]North Dakota State University, Fargo, ND (48)

The era of organic compounds for weed control in agriculture began following World War II and continues through today. Organic pesticides are the most common means to control pests in agricultural crops and had a global market value of $56 billion in 2012 according to a 2017 United States Environmental Protection Agency report. The use of herbicides to control weeds accounts for the largest component of pesticide use, representing 44% of global pesticide sales, followed by insecticide (29%), fungicide (26%) and others (1%). Today, pesticides frequently are the sole strategy for controlling pests. Weeds, in the beginning, were hand-pulled. Later various farm animals pulled crude implements to till soil to remove weeds. In the early 20th century agronomists such as A. C Arny at the University of Minnesota evaluated salts, such as sodium chlorate for the control of perennial weeds. Likewise, H. L. Bolley at North Dakota State University, beginning in 1896, assessed inorganic compounds and solutions of copper salts for selective control of broadleaf weeds in cereals. Early accounts emphasized integrated weed control strategies by seed growers for weed eradication and focused primarily on control of perennial weeds. Recommendations in 1930 for annual weed control included precise weed identification, crop rotations with forages, and tillage to deplete the weed seed bank. Modern day production agriculture emphasizing organic herbicides struggles with herbicide-resistant weeds. Agriculturalists can learn by reconsidering the integrated management strategies previous generations deployed for weed management.

Investigating Clopyralid Resistance in *Ambrosia artemisiifolia* (Common Ragweed) Using RNA Sequence Transcriptome Analysis. Nash D. Hart*[1], Erin E. Burns[2], Eric L. Patterson[2]; [1]Michigan State University, Durand, MI, [2]Michigan State University, East Lansing, MI (49)

Ambrosia artemisiifolia (common ragweed) is a globally distributed, difficult to control weed species that can cause extensive crop yield reductions unless appropriately managed. Clopyralid is a synthetic auxin herbicide commonly used to control *A. artemisiifolia* and other weeds in the Asteraceae family. In 2018, a population of *A. artemisiifolia* was discovered in a Michigan Christmas tree farm that is highly resistant to clopyralid, surviving at clopyralid doses thirty-two times the recommended field use rate. Chemical weed control is a mainstay in most agricultural systems in the North Central region and herbicide resistance threatens its effectiveness; therefore, it is essential to understand the mechanism of resistance that allows weed species to become resistant to herbicides. To this end, we have begun investigating potential resistance mechanisms in this clopyralid resistant *A. artemisiifolia* population using RNA-seq. As no well-curated genome or transcriptome currently exists for this species, we first built a reference transcriptome *de novo* using Trinity and reads from the susceptible population. Next, we aligned all reads from one resistant and one susceptible population using the program HISAT2. We identified all assembled Aux/IAA annotated transcripts using BLAST and manually screened the read alignments for polymorphisms (SNPs, InDels, etc.) that distinguished resistant from susceptible individuals. We specifically evaluated the sequence motif known as "the degron" which has previously been shown to be involved in target site resistance (TSR) to other auxinic herbicides including 2,4-D and dicamba in other dicot species. We also performed a whole transcriptome differential expression analysis to identify resistance mechanisms that involve changing gene expression (i.e. non-TSR and target site over-expression). Lastly, we performed a Gene Ontology (GO) enrichment analysis on the RNA-seq differential expression data to identify global differences in the transcriptomes of these two populations. After searching the entire genome there were fifteen transcripts containing the Aux/IAA degron sequence. Six out of the fifteen transcripts containing the sequence contained a polymorphism. Zero of those transcripts had a significant polymorphism that correlated perfectly with the resistant phenotype. Differential expressional analysis highlighted 536 genes that were significantly differentially expressed, with 179 being overexpressed in the resistant population and 357 being overexpressed in the susceptible. Out of the 536 genes, there were 241 genes that had a log fold change of greater than two or less than negative two and a p-value less than 0.01. Interestingly 201 genes were overexpressed in the susceptible population and only 40 genes overexpressed in the resistant population. Within the 241 genes, there are many genes of interest that directly relate to the auxin pathway, such as auxin response factors and ABC transporter genes, as well as genes associated with non-TSR, such as cytochrome P450s. Ultimately, understanding clopyralid resistance in *A. artemisiifolia* and the potential for cross resistance to other auxinic herbicides is of critical importance for continued agricultural productivity in the North Central region as technologies like Enlist, Xtend, and XtendFlex soybean become more common.

The Genomic Response of *Kochia scoparia* to Sub-lethal Doses of Glyphosate. Carly A. Claucherty*[1], Todd A. Gaines[2], Eric L. Patterson[1]; [1]Michigan State University, East Lansing, MI, [2]Colorado State University, Fort Collins, CO (50)

Genomic structural variation is a form of genetic diversity that enables adaptation and has been exploited by weedy species to confer herbicide resistance. Glyphosate resistance (GR) in kochia (*Kochia scoparia*) is caused by gene amplification of 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) and this copy number variation (CNV) is also a GR mechanism in seven other weed species. Few studies have characterized these spontaneous genomic rearrangements in plants or focused on understanding the role that they play in gene expression. In this study, whole genome bisulfite sequencing and RNA sequencing was performed using young leaf tissue from the susceptible kochia line 7710 before and three weeks after application of low (79 g a.e. ha^{-1}) and medium (158 g a.e. ha^{-1}) sublethal rates of glyphosate. Here we identify the native methylation status of kochia and observe differential methylation across the genome, and its interplay with the transcriptome following glyphosate application. These findings provide novel information on the adaptive role of whole genome structural variation in response to herbicide selection pressure.

Reduced Translocation of 2,4-D Observed in Resistant *Plantago lanceolata*. Quincy D. Law*[1], Ronald R. Rogers[2], Travis Gannon[2], Aaron Patton[3]; [1]North Dakota State University, Fargo, ND, [2]North Carolina State University, Raleigh, NC, [3]Purdue University, West Lafayette, IN (51)

Investigating the mechanism(s) of 2,4-D resistance in buckhorn plantain may help to inform management practices and preserve herbicidal efficacy. Given that the 2,4-D resistance is likely a non-target mutation, altered absorption and/or translocation as mechanisms of resistance were tested using radiolabeled [^{14}C]2,4-D and comparing resistant buckhorn plantain with a susceptible ecotype. The objective of this experiment was to determine if absorption or translocation play a role in 2,4-D resistance in a resistant buckhorn plantain ecotype. Plants were oversprayed with 2,4-D at a rate of 1.68 kg ae ha^{-1} with the youngest fully-expanded leaf excluded. The isolated leaf was then treated with four 0.5-µl droplets of radiolabeled [^{14}C]2,4-D on the adaxial leaf surface, avoiding prominent veins, for a total of 5.32 kBq $plant^{-1}$. Plants were harvested at 24, 96, and 192 HAT and separated into treated leaf, treated leaf wash, nontreated shoots, and the caudex + roots. The clearest difference between the resistant and susceptible ecotype was the interaction between ecotype and harvest period for [^{14}C] from 2,4-D in the non-treated shoots. After 192 hr, the susceptible ecotype had a higher amount of [^{14}C] from 2,4-D in the non-treated shoots (16.1%) than the resistant ecotype at any of the harvest periods (5.4-7.3%); the amount of [^{14}C] from 2,4- D in the non-treated shoots was similar across all three harvest periods for the resistant ecotype. Thus, reduced translocation plays an apparent role in 2,4-D resistance in buckhorn plantain.

Role of Glyphosate Retention and Absorption on Tolerance of Two Horseweed Growth Types. Justine L. Fisher*, John A. Schramski, Eric L. Patterson, Christy Sprague; Michigan State University, East Lansing, MI (52)

Glyphosate-resistant horseweed (*Erigeron canadensis* L.) is a problematic weed for Michigan growers. Recent shifts from a winter annual to a primarily summer annual lifecycle have created novel horseweed management challenges. Additionally, phenotypic differences in newly emerged horseweed growth types, "rosette" and "upright/bolted", have been observed co-occurring in the same field. Previous research found that "upright" plants from two glyphosate-resistant populations were 4- and 3-fold less sensitive to glyphosate than their rosette siblings. However, differences in sensitivity between the two growth types in the susceptible population were not observed. Further experiments were conducted to investigate whether differences in glyphosate sensitivity between rosette and upright growth types in resistant and susceptible populations are due to glyphosate retention on the leaf or absorption of glyphosate. Seed from the same parent plant was used to obtain the two growth types. To stimulate the upright growth type, seeds from resistant and susceptible populations were exposed to a 4-week vernalization period then placed in the greenhouse with seed planted for the rosette siblings. Four weeks after emergence upright plants were 6-cm tall and 10-cm wide, while rosette plants were 2-cm tall and 9-cm wide. These plant sizes were used for the glyphosate retention and absorption experiments. Horseweed plant interception and retention of glyphosate were examined by applying 1.27 kg ae h^{-1} of glyphosate with Chicago Sky Blue dye. Immediately after application, plants were rinsed and absorbance of the rinsate was measured with a spectrophotometer at 625 nm. Horseweed plants were then harvested and leaf area and biomass per plant were measured. Glyphosate absorption was determined by spotting 10 1- droplets of 1.67 kBq of ^{14}C glyphosate on horseweed plants that were oversprayed with 1.27 kg ae ha^{-1} of glyphosate. The treated leaf for each population was one of the uppermost fully developed leaves per plant and this leaf was covered during the pretreatment process. The treated leaf was excised at 0, 12, 24, 72, and 168 h after treatment (HAT) and the remaining ^{14}C glyphosate was washed off the leaf surface with 4 ml methanol-water (1:9 ratio). Radioactivity in each sample was quantified by liquid scintillation spectrometry. The experiment was a randomized complete block design with five replications and was repeated in time. There were no differences in ^{14}C glyphosate absorption between the rosette and upright types in the glyphosate-resistant or -susceptible populations. The estimated time to reach 50% glyphosate absorption for each biotype was 10-13 HAT and by 21-27 HAT each population had reached 75% absorption. Total glyphosate absorption 168 h after application ranged between 85-90% for each population and growth type. These results suggest that differences in glyphosate sensitivity among the rosette and upright growth types in the resistant population and between the resistant and susceptible populations were not due to differences in glyphosate absorption. We are currently examining if glyphosate sensitivity between growth types may be due to glyphosate translocation.

Inheritance of Resistance to ALS-Inhibitors in Giant Ragweed is Controlled by Multiple Genetic Factors. Benjamin C. Westrich*, Bryan G. Young; Purdue University, West Lafayette, IN (53)

Giant ragweed (*Ambrosia trifida* L.) biotypes resistant to acetolactate synthase (ALS)-inhibiting herbicides via a W574L mutation in the ALS gene have been documented in seven US states and Ontario, Canada. Just one mutant allele in this diploid species results in resistance to herbicide rates far greater than those used in crop production. As this mutation bares no fitness penalty, and because ALS is a nuclear gene, inheritance of resistance was assumed to follow the principles of Mendelian genetics. However, both field-based surveys and controlled greenhouse crosses have shown homozygous-mutants to be nearly absent from one population (Ti18). We hypothesized that giant ragweed may possess self-incompatibility (SI), and that the SI and ALS genes are linked. If true, pollination between two gametes possessing mutant ALS alleles that also shared SI alleles would result in an SI response, thus preventing the union of gametes carrying the resistance mutation. To explore this hypothesis, we first tested for the presence of SI by evaluating self- vs cross-pollination. Self-pollination resulted in 70 to 80% less pollen retention, pollen tube growth, and seed production compared with cross-pollination, indicating that giant ragweed possesses SI. Next, intra- and inter-population crosses were conducted to track the inheritance of the W574L mutation. We believed that inter-population crosses would be more likely to share compatible SI alleles, leading to Mendelian inheritance of ALS in the F1 generation. Interestingly, we identified non-Mendelian inheritance in nearly half of the 63 unique crosses conducted in this experiment, and in all three populations tested. Contrary to our hypothesis, both internal and external crosses sometimes resulted in abnormal inheritance of ALS, with no clear difference between the two strategies. As homozygous-mutant progeny were absent from the majority of the external crosses, it appears that the mutant ALS allele tends to arise most often in plants that also share a common SI allele. Shared linkage of a common SI allele and wild-type ALS allele (leading to the production of solely heterozygous progeny) was also evident in some crosses. This could have been driven by an initial herbicide selection event, which would have reduced the total number of unique SI alleles linked to wild-type ALS alleles. Considering the results from all crosses, fewer mutant alleles were found in F1 progenies than would be expected under Mendelian inheritance because of the rarity of homozygous-mutant biotypes. However, the resistant phenotype was often overrepresented in F1 generations of crosses that involved the Ti18 population, with some crosses resulting in a 5x increase in the number of resistant seeds produced. Overall, the linkage of SI and ALS genes could serve to increase the retention of susceptible alleles in a population by favoring heterozygosity, though a lack of SI allele diversity could greatly increase the rate of spread of a dominant resistance mutation like W574L. Ultimately, direct confirmation of this linkage and its effect on the inheritance of ALS will require a greater understanding of the giant ragweed genome and the specific SI system.

A KASP Assay for Sex-Determination in Palmer Amaranth (*Amaranthus palmeri*) and Application in Weed Ecology. Ednaldo A. Borgato*, Sathishraj Rajendran, Anita Dille, Mithila Jugulam; Kansas State University, Manhattan, KS (54)

Palmer amaranth is a summer annual, C4, with fast growth rate, highly prolific, and dioecious weed. Recently, the Palmer amaranth genome became publicly available, and studies focused on aspects of evolution and dioecy identified a male-specific (MSY) molecular marker in the Y pseudo-chromosomal region (approximately 1.5 Mb and 120 genes) in this species. Here, we propose a KASP assay based on the MSY markers for sex-determination and subsequent application in ecology studies. A set of MSY primers previously made available were adapted for KASP assay adding the HEX and FAM tails to the forward primer for testing with the regular MSY reverse primer for allelic discrimination, using the MSY as dominant marker. Additionally, reactions were performed using various concentrations of DNA (10 to 90 ng) isolated from the known male and female plants (gender was confirmed upon flowering) to optimize the assay for identifying the marker. Further, an inter-gender competition study was conducted in the greenhouse with male and female individuals under the following densities and proportions: 1, 4 and 8 plants per pot at 100:0, 75:25, 50:50, 25:75 and 0:100 male to female ratios to understand competitive interactions [e.g., branching (mechanism that favors seed production), seed production per plant, days to flowering and maturity, etc]. We expect to obtain robust data explaining interactions between male and female Palmer amaranth plants and potentially identify opportunities for successful management, specifically reducing seed production.

Soil Applied PPO Inhibitors Select for Fewer Resistant Individuals Than Foliar Applications. Jesse A. Haarmann*, Bryan G. Young, William G. Johnson; Purdue University, West Lafayette, IN (55)

Resistance to PPO inhibiting herbicides in waterhemp (*Amaranthus tuberculatus* (Moq.) J.D.Sauer) is primarily conferred by the ΔG210 mutation in the PPX2 gene. Soil applications of PPO inhibitors provide partial control of resistant populations at the cost of a reduced length of residual activity and greater frequency of surviving individuals resistant to PPO inhibitors. Trifludimoxazin is a PPO-inhibiting herbicide currently under development that has soil and foliar activity and has been documented to control PPO inhibitor resistant waterhemp (ΔG210 and R128G) in foliar applications. Control of current PPO inhibitor-resistant biotypes is attributed to unique binding properties of trifludimoxazin to the PPX2 enzyme, but it is unclear if selection for ΔG210 individuals is still occurring after soil or foliar applications. Our objective was to determine if applications of trifludimoxazin select for PPO-inhibitor resistant individuals when applied PRE or POST similarly to other PPO inhibitors, and determine if combinations of trifludimoxazin with other PPO inhibitors can reduce selection for PPO-inhibitor resistant individuals. Separate PRE and POST field experiments were conducted in 2020 and 2021 at two Indiana locations. Trifludimoxazin, saflufenacil, and fomesafen were applied PRE or POST at rates of 12.5, 25, and 263 g ai ha^{-1}, respectively, along with all two- and three-way combinations of those herbicides and a no herbicide control. Leaf tissue from the first 25 plants emerging in each plot in the PRE experiment were collected and also from 25 surviving plants in each plot from the POST experiment. Plant tissue samples were used for DNA extraction and subsequent qPCR assays for the ΔG210 mutation. Overall, a greater number of PPO inhibitor resistant plants survived PPO inhibitor foliar applications than emerged through PPO herbicide soil applications. Trifludimoxazin did not increase the frequency of PPO inhibitor-resistant individuals when applied to soil, but increased the frequency of PPO resistant individuals by 2.5 to 2.6 fold when applied to foliage similar to other PPO inhibitors. Despite selection for PPO inhibitor resistance, herbicide combinations increased the length of residual control and, therefore, fewer waterhemp plants survived, which reduces the reliance on subsequent herbicide applications or other non-chemical practices to control surviving waterhemp plants. Future research is justified to determine if trifludimoxazin selects for other mutations or mechanisms of resistance related to the PPO enzyme.

Isolation of Protoplasts from Waterhemp Cell Suspension Cultures. Robert P. Sabba, Michael J. Christoffers*; North Dakota State University, Fargo, ND (56)

Plant tissue culture is a useful biotechnology for researchers wanting to study physiological processes in a laboratory setting. When cultures are maintained as undifferentiated cells, genetic experimentation can also be performed without risk of seed or pollen escaping the laboratory. Plant protoplasts are particularly useful in genetic experimentation because their lack of a cell wall facilitates introduction of nucleic acids for transformation and gene editing experiments. However, successful generation of plant protoplasts often requires adaptation of existing methods to individual species. We investigated the conditions necessary to isolate protoplasts from waterhemp [*Amaranthus tuberculatus* (Moq.) J. D. Sauer], using cell suspension cultures as a source of tissue. The waterhemp cell suspension cultures were originally derived from callus tissue grown from waterhemp seedling hypocotyls. Protoplasts were successfully obtained by incubating suspension-cultured cells in an aqueous solution with cell wall-digesting enzymes Cellulase Onozuka RS and Macerozyme R-10, plus mannitol as an osmoticum and calcium for membrane stability. Other enzyme combinations did not successfully digest cultured waterhemp cell walls. Protoplast viability was assessed microscopically using Evans blue and fluorescein diacetate (FDA), which stain dead and live cells, respectively. Protoplast viability ranged from 72-78%, indicating the potential utility of this protocol in future waterhemp research involving tissue cultured cells.

Population Structure and Adaptation of Weedy *Lolium* spp. Revealed by a Continental Transcriptomic Study. Lucas K. Bobadilla*[1], Brent P. Murphy[2], Anita Küpper[3], Roland S. Beffa[4], Patrick Tranel[2]; [1]University of Illinois, Champaign, IL, [2]University of Illinois, Urbana, IL, [3]Bayer Crop Science, Frankfurt, Germany, [4]Bayer Crop Science, Frankfort / Main, Germany (57)

The *Lolium* genus is mainly represented by eight species, which are known to be highly adaptable to multiple environments and can be found worldwide. *Lolium* spp. are obligate outcrossing and can freely hybridize. The *Lolium* genus occupies a unique position within agriculture. As one of the main forage crops, many breeding efforts were made to improve traits of interest. In contrast, several species within the genus, including escapes from cultivated areas, are recognized as problematic weeds in agricultural and natural environments. Routinely, weed scientists often focus only on the effect of management practices; however, because weeds interact with more than just management systems, factoring in the environment is an essential consideration for why weeds are present. Due to the vast natural range of *Lolium*, understanding the population structure within a large region can provide insights into weed adaptation. The study objectives were to estimate the population structure and identify adaptation patterns to environmental factors in *Lolium* in Europe via transcriptomics. *Lolium* individuals across western Europe were collected from 34 agricultural fields. RNA libraries from each of 131 individuals were prepared using RNeasy Plant Mini Kit and sequenced with Illumina Hiseq. Fifteen environmental parameters were obtained from each collection site using E-OBS and European Soil databases. *De-novo* transcriptome assembly was conducted using Trinity and read counts acquired using Bowtie2/RSEM. Variants were called using the standard GATK pipeline. Population structure was conducted using ADMIXTURE, testing four different k-values. The best k-value was chosen based on the lowest cross-validation error. Once subpopulations were identified, a differential expression (DE) and an enrichment analysis using EdgeR and TopGO were conducted. Pearson correlation was assessed between environmental parameters and population structure. From environmental parameters showing correlation with population structure, a genome-wide association study (GWAS) was conducted within GAPIT using Blink with 1,000 permutations to identify quantitative trait nucleotides (QTNs). Two subpopulations with admixture/hybridization were identified within European weedy *Lolium*, of which their distribution was correlated with a longitudinal variation. Over 5,000 differentially expressed genes were identified, which, according to enrichment analysis, were involved mainly with plant organ development, flowering processes, soil nutrient transport, hormone transport, and response to abiotic stimuli. From the 15 environmental parameters, 8 showed a significant correlation with population structure variation, indicating that differences in subpopulations are due to differential adaptation for soil variables and frost-free day length. GWAS indicated 30 QTNs correlated with five environmental factors, with a specific 3-Mb region at chromosome 5 containing 11 QTNs for all traits. QTNs are at genes related to environmental adaptation, such as cytokinin activation and transcription factors involved with flowering time and root nutrient uptake. Together, our analyses point to two distinct subpopulations adapted to environmental factors including soil factors and growing-season length, illustrating the remarkable plasticity and adaptability of *Lolium* spp.

The Functional Annotation of Weedy Genomes for the International Weed Genomics Consortium. Nathan D. Hall*, Eric L. Patterson; Michigan State University, East Lansing, MI (58)

Functional annotation is a critical step in the democratization of weed genomics; it provides end users with easy access to sensibly named genomic features, reduces analytical redundancy and allows end users to focus on their chosen area of research. Here we present the functional annotation method implemented by International Weed Genomics Consortium. Our functional annotation pipeline address three general types of categorizations, within gene, within cell and within taxon. Within gene annotation is carried out through the implementation of Interpro Scan which leverages multiple annotation methods to label, compare and score functional domains within each predicted protein. Within cell annotation is carried out through Multiloc2 a machine learning method built on a trained support vector machine model, and supplemented with pathway labels taken from Interpro Scan. Within taxon annotation is carried out by sequence similarity searches with MMSeqs2 against two curated databased, Uniref_50 and the proteomes of over 200 previously sequenced genomes taken from NCBI. All results are saved into a JSON format, and a subset of results are used to write a full featured genome feature file (gff3) for use in genome browsers.

The Importance of Weed Control in Vineyards. Michelle M. Maile*; University of Missouri, Columbia, MO (59)

Weed management in grapevines (*Vitis vinifera*) is necessary to preclude both competition as well as challenges with mechanical berry harvest. Many growers in Missouri rely upon repeated applications of paraquat, glufosinate and glyphosate, which often results in late-season populations of annual grasses. Public concern regarding glyphosate safety, as well as new restrictions on the use of paraquat will require vineyard managers to consider diversifying herbicide usage and timing. A recent weed survey revealed that perennial weeds such as white clover (*Trifolium repens* L.) and horsenettle (*Solanum carolinense* L.) are frequently found in vineyards, along with a host of annual weeds. Effective weed management necessitates a PRE followed by POST program. At two locations in Missouri in 2020 and 2021, fall or spring applications of indaziflam, flumioxazin, and flazasulfuron effectively suppressed winter annuals. However, only spring applications reduced annual grass biomass versus untreated control plots. Spring POST applications of glufosinate on PRE- treated areas resulted in promising control of annual weeds. Spring POST + PRE applications resulted in up to 70% greater reductions in weed biomass compared to areas treated with repeated applications of glufosinate or mixed applications of glyphosate, glufosinate or paraquat. Inclusion of a grass-selective herbicide (fluazifop) was highly effective in POST treatments at reducing annual grasses in MO vineyards. Research in production vineyards with PRE + POST programs provides evidence of successful weed management programs that do not rely as heavily on traditionally utilized chemistries.

The Performance of Halauxifen-methyl + Fluroxypyr + 2,4-D Choline (GameOn^{TM}) in Golf Native Area Weed Management Programs. David E. Hillger*, Amy L. Agi, Paul T. Marquardt; Corteva Agriscience, Indianapolis, IN (60)

Halauxifen-methyl + fluroxypyr + 2,4-D choline herbicide (GameOn®) is a new weed management tool available for non-residential turf weed management. Studies were conducted in 2021 to explore the utility of GameOn for managing weeds in native areas found in and around golf courses. Trial results indicate that weed control with GameOn was significantly better than the standard control program of 2,4-D + MCPA + dicamba (Trimec Classic) and equally as effective as aminopyralid + 2,4-D (NativeKlean®) on most species tested. GameOn had greater efficacy on *Asclepias spp.* compared to the control achieved with NativeKlean. The control of *Cirsium arvense* was better with NativeKlean compared to Trimec Classic or GameOn. Turf tolerance to GameOn was also evaluated for several native grass species typically planted in golf course native areas including *Festuca spp., Bouteloua spp., and Andropogon spp*. Little to no injury was observed with any of the species evaluated. The use of GameOn in golf course native areas provides a valuable tool for course superintendents as they are looking for effective, sustainable weed control programs. TM® Trademarks of Corteva Agriscience and its affiliated companies

Peppermint (*Mentha* × *piperita*) Response to Mesotrione and *S*-Metolachlor Applied Post-Harvest. Jeanine Arana*, Stephen L. Meyers; Purdue University, West Lafayette, IN (61)

Amaranthus species are the most troublesome weeds in Indiana peppermint production and can dramatically reduce the yield of mint hay and oil. Additionally, weeds contaminate mint hay and oil, reducing its quality and value. Unfortunately, current herbicide options for Indiana mint farmers are limited, and no Group 15 or 27 herbicides are registered for use in the state. *S*-metolachlor (Group 15) and mesotrione (Group 27) herbicides can effectively control *Amaranthus* species. To better understand the impact of *S*-metolachlor and mesotrione on peppermint tolerance and yield, we determined the dose-response curves of peppermint to both herbicides. Two dose-response greenhouse trials for each herbicide were conducted at the Purdue University Horticulture Greenhouses, West Lafayette, IN, in 2021. The experimental unit consisted of a 20 cm polyethylene pot into which four shoot tip cuttings were planted. Treatments included five rates: 0, 1000, 2000, 3000, and 4000 g ai ha^{-1} for *S*-metolachlor, and 0, 105, 210, 420, and 840 g ha^{-1} for mesotrione. Treatments were applied the same day of a simulated harvest for the *S*-metolachlor trials and one day after harvesting for the mesotrione trials. Visual crop injury was rated on a scale of 0% (no injury) to 100% (crop death). Height measurements of five shoots in each pot were recorded 14, 28, and 42 days after treatment (DAT)for the *S*-metolachlor, and 14, 28, 42, and 52 DAT for the mesotrione trials. Aboveground biomass samples were harvested 42 DAT for the *S*-metolachlor and 52 DAT for the mesotrione trials. Samples were dried at 60°C for three days. Data were subjected to ANOVA and then to non-linear regression analysis. At 14 DAT, *S*-metolachlor rates increased from 1000 to 4000 g ha^{-1}, decreased height from 29 to 67%, and increased visual crop injury (necrosis, stunting, and leaf distortion) from 35 to 70%. At 28 DAT, they decreased height from 8 to 38% and increased visual crop injury from 1 to 40%. At 42 DAT, plants had recovered entirely, and dry weight was not reduced at any of the rates applied. In contrast, at 52 DAT, mesotrione rates increased from 105 to 840 g ha^{-1}, reduced height from 12 to 78.6%, and increased visual crop injury (bleaching, stunting, and leaf distortion) from 4 to 84%, resulting in a significant dry weight reduction from 42 to 98%. Based on these results, applying *S*-metolachlor post-harvest at 1000 g ha^{-1} may be a safe and efficacious method of *Amaranthus* control in peppermint. However, mesotrione is not recommended at the rates used in this study due to its severe impact on peppermint injury and dry weight.

Tolerance of 'Tina Gold' Mum to Reduced Rates of Glyphosate, 2,4-D, and Dicamba. Laura Rodriguez*, Stephen L. Meyers, Jeanine Arana, Nathaly Vargas; Purdue University, West Lafayette, IN (62)

In 2020, commercially grown potted mum plants exhibiting epinasty were submitted to the Purdue Plant and Pest Diagnostic Laboratory. The cause was likely off-target herbicide movement. A shade house experiment was conducted at Meigs Horticulture Research Farm in Lafayette, IN in the summer of 2021 to evaluate the response of 'Tine Gold' chrysanthemum (*Chrysanthemum morifolium*) to 2,4-D, dicamba, and glyphosate applied at three different times. The experiment was a three-way factorial design. Sublethal doses consisted of 1/X, 1/10X, 1/100X, 1/500X and 1/1000X of the recommended field rates of glyphosate (868 g ha^{-1}), dicamba (559 g ha^{-1}), and 2,4-D (1066 g ha^{-1}). Application timings were 9, 32 and 51 days after planting (DAP). The experimental unit consisted of a 20 cm polyethylene pot into which one rooted stem-cutting was hand-transplanted. In this abstract, we included plant height data collected at 51, 65 and 95 DAP and dry weight obtained from aboveground biomass harvested at 102 DAP. Plant height was measured from the surface of the pot to the top-center of the plant. Aboveground dry biomass was measured after drying the samples for three days at 60°C. Data were subjected to ANOVA. Results demonstrated that at 51 and 65 DAT, the 1x rates of 2,4-D and glyphosate significantly reduced height. 2,4-D caused 7% (51 DAT) and 3% (65 DAT) reduction, and glyphosate caused 15% (51 and 65 DAT) reduction. Dicamba had no significant effect on height at these timings. At 95 DAT, the three herbicides caused height reduction. 2,4- D reduced height by 19%, dicamba by 10%, and glyphosate by 12%. These results are consistent with the aboveground biomass weight because 2,4-D reduced biomass by 20%, dicamba by 28%, and glyphosate by 43%. Moreover, the 1X doses of all the herbicides reduced plant height 10-25% when applied 32 DAP, and 10-20% when applied 51 DAP, but not at 8 DAP. Based on these results we conclude that (1) chrysanthemums are tolerant to sublethal doses of 2,4-D, dicamba, and glyphosate herbicides and (2) they are susceptible to their 1X rates if applied at 32 or 51 DAP.

Cantaloupe Response to Simulated Flumioxazin Tank Contamination. Nathaly Vargas*, Stephen L. Meyers, Jeanine Arana, Laura Rodriguez; Purdue University, West Lafayette, IN (63)

In 2020, cantaloupe producers in Indiana reported excessive foliar necrosis following an application of clethodim plus 0.5% (v/v) non-ionic surfactant (NIS). The same producers used flumioxazin PRE in cantaloupe row middles prior to transplanting. To determine the interactive effects of clethodim, NIS concentration, and simulated flumioxazin tank contamination, a field trial was conducted at two locations at Meigs Horticulture Research Farm, Lafayette, IN in 2021. Plots, each 3.7 m long, consisted of a single row of six ´Athena´ cantaloupe (*Cucumis melo* L.) plants transplanted into black plastic mulch. The treatment design was a factorial of two clethodim rates (0 and 560 g ai ha^{-1}) by five NIS concentrations [0, 0.25%, 0.5%, 1%, 2% (v/v)] by two flumioxazin rates (0 and 7 g ai ha^{-1}). Data collection consisted of visual crop injury (0 to 100%) at one, two and four weeks after treatment (WAT) and yield. Our results demonstrated that the presence of flumioxazin caused significant injury on cantaloupe plants at 1 WAT. Pulled across all clethodim and NIS rates, flumioxazin resulted in 80 and 86% crop injury at the two sites compared to $\leq$ 9% injury from clethodim and NIS without flumioxazin. Phytotoxicity included chlorosis, necrosis, stunting, leaf distortion, and fruit blemishes. Flumioxazin damage was worse when clethodim and NIS were present. Pulled across all clethodim and flumioxazin rates, cantaloupe injury 1 WAT increased from 38 to 64% and 27 to 54% as surfactant concentration increased from 0 to 2%, at the two sites respectively. Despite significant injury at 1 WAT, injury was transient. By 4 WAT injury from all treatments was $\leq$9%. Moreover, total cantaloupe fruit number did not differ among treatments. We confirmed that the injuries in cantaloupe reported by growers in 2020 were consistent with flumioxazin tank contamination.

Suppression of Horseweed in Sugarbeet with Cereal Rye. Brian J. Stiles II*, Christy L. Sprague; Michigan State University, East Lansing, MI (64)

The use of cover crops as a weed suppression tool is becoming increasingly popular amongst cropping systems in the United States due to herbicide-resistant weeds. Glyphosate-resistant (GR) horseweed (*Erigeron canadensis* L.) is a significant problem in for sugarbeet growers in the Michigan fields and new management approaches are needed. One approach that has been shown to suppress horseweed in other cropping systems is cereal rye. From 2019 to 2021, field studies were conducted in East Lansing, Michigan to evaluate the use of cereal rye as a part of a management program for glyphosate-resistant horseweed in sugarbeet. 'Wheeler' cereal rye was drilled at 67 kg ha^{-1} in the fall prior to each sugarbeet year. This study was established in a split-plot design with cereal rye termination as the main plot factor and herbicide treatment as the sub-plot factor. Cereal rye termination consisted of applying glyphosate at 1.27 kg ae ha^{-1} + ammonium sulfate. Cereal rye termination treatments included: early burndown (EBD) 14 d prior to sugarbeet planting, burndown at planting (PBD), PBD + roller, and PBD + roller crimper, and a delayed burndown (DBD) 7 d after planting. These treatments were compared with a no cover control. In 2020 and 2021, additional treatments included a sugarbeet that was strip-tilled prior to planting with a DBD ST and no cover control. The three herbicide management treatments consisted of two POST applications at the 2- and 6-8 leaf sugarbeet stage. The treatments included: 1) glyphosate twice (control), 2) glyphosate (0.84 kg ae ha^{-1}) followed by glyphosate (0.84 kg ae ha^{-1}) + clopyralid (0.12 kg ha^{-1}) and 3) glyphosate (0.84 kg ae ha^{-1}) + clopyralid (0.06 kg ha^{-1}) followed by glyphosate (0.84 kg ae ha^{-1}) + clopyralid (0.12 kg ha^{-1}). Cereal rye biomass at planting was 740, 745 and 1,150 kg ha^{-1} and was 5-, 2.5- and 6-times higher at the time of DBD in 2019, 2020 and 2021, respectively. Early-season horseweed suppression was greatest with the DBD treatment. By mid-July, regardless of termination time or method horseweed biomass was at least 38-64% lower than the no cover control in 2019 and 2020 respectively. However, in 2021 none of the cereal rye cover crop treatments suppressed horseweed. Horseweed biomass at sugarbeet harvest was as much as 70% lower than the no cover control when a cereal rye cover crop was used in 2019. However, in 2020 and 2021 horseweed suppression at sugarbeet harvest was not influenced by any of the cover crop treatments compared with the no cover control. The main effect herbicide treatment showed that regardless of the number of clopyralid applications horseweed biomass was reduced compared with the control in all three years. In 2019, two applications of clopyralid provided greater horseweed biomass reduction than one clopyralid application. Sugarbeet yield was reduced in the DBD treatment in all three years due to reduced sugarbeet growth, however when strip-till was included sugarbeet yield was higher. Regardless of clopyralid treatment, sugarbeet yields were similar in 2019 and 2020 and were not different than the control in 2021. Cereal rye has shown some positive signs of horseweed suppression in sugarbeet, however these results can be variable. While the greatest horseweed suppression generally occurred with the DBD, sugarbeet yield was also suppressed. However, the addition of strip-till to the DBD treatments were often beneficial for increasing sugarbeet yield.

Tolerance of Volunteer Hemp to Spring Burndown Herbicides in Soybean. Alina Gava*, Milos Zaric; University of Nebraska Lincoln, North Platte, NE (65)

An increase in industrial hemp cultivation throughout the diverse crop rotations in the US has caused concerns regarding the appearance of subsequent volunteer hemp. No herbicide is currently registered for industrial hemp in the US, and knowledge on volunteer hemp control options is limited. The objective of this study was to evaluate the resilience of volunteer hemp to commonly used herbicides for spring burndown in soybean. A trial was conducted under field conditions in a completely randomized design with 21 treatments, including non-treated control, with each treatment replicated four times. Evaluated active ingredients included glyphosate, 2,4-D, sulfentrazone, cloransulam-methyl, metribuzin, carfentrazone-ethyl, flumioxazin, pyroxasulfone, imazethapyr, and saflufenacil applied alone or in combination. All treatments were applied according to the product labels at a carrier volume of 140 L ha^{-1} at 15 cm plant height using a TTI11002 nozzle at 221 kPa. Visual evaluation of injury was evaluated at 7, 14, 21, and 28 days after application (DAA). At 28 DAA, plant biomass was harvested from an area of 0.093 m^2 and oven-dried at 65°C to reach a constant weight. The dry weights were recorded and used for further analysis. Dataset was analyzed using a generalized linear mixed model in Statistical Analysis Software, with treatment comparisons performed using a Tukey's test at significance level a = 0.05. Volunteer hemp exhibited increased sensitivity to glyphosate alone or tank-mixed with other active ingredients, with 90% biomass reduction when applied alone and 95% when combined with sulfentrazone plus metribuzin. In general, 2,4-D treatments were more effective when sprayed in tank-mixture with other herbicides. The pyroxasulfone alone or in combination with saflufenacil and imazethapyr did not affect biomass reduction. Results indicated that a variety of chemical control options could be utilized effectively in soybean for volunteer hemp control. Also, tolerance to active ingredients occurred at multiple instances, suggesting potential use in industrial hemp, with further evaluation required to understand consequences when used in crop situations.

The Response of Jack-o'-lantern Pumpkins to Fomesafen Herbicide. Luz Aide Cardona Giraldo*, Stephen L. Meyers, Jeanine Arana; Purdue University, West Lafayette, IN (66)

Indiana is ranked third among the top pumpkin-producing states in the United States with an average of 5,000 acres valued at $16 million. Pumpkins are usually direct-seeded into bare ground beds placed 1.2 to 1.8 meters apart. The wide row spacing that is required for growth of this crop allows weeds to establish easily. Fomesafen, a group 14 PPO-inhibitor, is registered for pre-emergence use after pumpkin seeding but before crop emergence in some North Central US states, but not in Indiana. We performed four herbicide dose-response trials in 2020 and 2021 at Wanatah and Vincennes, IN, to determine pumpkin tolerance to fomesafen. Experimental units consisted of a plot of 9.76 m^2, which contained three 4.9 m long bare ground raised-bed rows. In each row, we hand-seeded four pumpkins. The experiment had a factorial treatment arrangement of two pumpkin varieties ('Bayhorse Gold' and 'Carbonado Gold') by five fomesafen rates (0, 280, 560, 840 and 1220 g ai ha^{-1}). The experiment design was a randomized complete block with four replications. Fomesafen was broadcast across the plot after planting. Data collection included visible crop injury on a scale of 0% (no injury) to 100 % (crop death) 4 and 6 weeks after treatment (WAT). At harvest, we recorded the weight and color of each fruit and classified them as marketable if weight was = 1.50 kg and > 50% of the surface area was orange. Data were subjected to ANOVA and then to non-linear regression. Data were analyzed separately by year. In 2020 at Vincennes, as fomesafen rate increased from 280 to 1120 g ha^{-1}, pumpkin emergence decreased from 72 to 26%, and crop injury increased from 9 to 20% at 4 WAT and from 1 to 11% at 6 WAT. Fomesafen at 560 to 1220 g ha^{-1} reduced yield 30 to 65% compared to the control. However, fomesafen at 280 g ha^{-1}, the 1x rate in other states, resulted in pumpkin yield similar to the control. In 2021, fomesafen reduced pumpkin emergence 6 to 30%. However, yield was not reduced at any rate. In Wanatah crop injury increased from 4 to 50% at 4 WAT and from 1 to 21% at 6 WAT as fomesafen rates increased from 280 to 1220 g ha^{-1}, respectively. At Vincennes crop injury at 4 and 6 was < 12% for all treatments. Yield reduction in 2020 likely resulted from 48 mm of rainfall within three days after treatment (DAT), while in 2021, rainfall was limited to 7 mm within 3 DAT at Vincennes and 21 mm within 5 DAT at Wanatah. Moreover, crop injuries in 2021 are consistent with this idea because at Wanatah it rained more and injuries were greater than at Vincennes where it rained less. Based on these results we can conclude that the rate of 280 g ha^{-1} is safe for use in pumpkins and that risk of crop injury appears to increase with increasing rainfall.

Determining an Effective Yet Economical Pendimethalin Application for Early-season Weed Control in Onion. Harlene M. Hatterman-Valenti*, Avery Shikanai, Collin Auwarter; North Dakota State University, Fargo, ND (67)

Early-season weed control in onion (*Allium cepa* L.) is challenging due to slow crop growth and poor competitive ability. Growers typically rely on multiple applications of residual and postemergence herbicides for season-long control. However, herbicides used in onion can be very expensive and repeated applications of herbicides at higher rates are costly and can cause unacceptable injury in current and succeeding crops. In addition, depending on the pendimethalin label, preemergence application to the onion crop may or may not be allowed. Therefore, we compared potential herbicide programs for early-season weed control that varied the total pendimethalin rate (0, 399, 799, 1598 g ai ha^{-1}), application timings (PRE, 1-, and 3-leaf stage), and other active ingredient combinations (DCPA, ethofumesate, flumioxazin, glyphosate, bromoxynil, and oxyfluorfen) at two irrigated sites (grower field (GF) and Oakes Research Extension Center (REC)). At GF 41 days after planting (DAP), herbicide programs that used 399 or 799 g ai ha^{-1} pendimethalin provided similar weed control as the best performing treatment. Likewise, at GF 61 DAP, all treatments provided excellent (90% >) control of redroot pigweed (*Amaranthus retroflexus* L.) and common lambsquarters (*Chenopodium album* L.), with no statistical differences between treatments. However, at REC, herbicide programs relying on any rate of pendimethalin applied PRE followed by oxyfluorfen at the one leaf stage provided unacceptable control of redroot pigweed 60 DAP. In contrast, treatments with pendimethalin applied at the one-leaf stage provided similar weed control as the best performing treatment. Together, these results demonstrate that as part of an integrated weed management program, reduced pendimethalin rates can provide effective control of redroot pigweed and common lambsquarters. However, failure of treatments that used pendimethalin applied PRE highlights the need for appropriate application timing and the need for more reliable weed control strategies in onion.

Roadside and Right-of-way Control of Glyphosate-resistant Johnsongrass (*Sorghum Halepense*). Sarah E. Dixon*; University of Missouri, Columbia, MO (68)

Unmanaged vegetation on roadsides and right of ways can decrease driver visibility, attract deer, and contribute to the spread of invasive and noxious weeds. Johnsongrass (*Sorghum halepense* (L.) Pers.) is one such weed species, and recent confirmation of a glyphosate-resistant (GR) biotype in Missouri necessitated evaluation of alternative options for chemical control in non-crop areas. At one location in Missouri in 2020, the objective of a field study with established GR johnsongrass was to evaluate the efficacy of fall-applied herbicides approved for use in non-crop areas. Rhizomes were collected in 2019, germinated in the greenhouse, and treated with glyphosate at 1736 g ae ha^{-1} at 20-30 cm in height. Surviving plants were transplanted into the field in rows on 7 June 2020. Mature plants were trimmed weekly during flowering in August and Sept. to 1.5 m height. On 16 Sept. 2020, treatments were applied via backpack sprayer calibrated to deliver 374 L ha^{-1} with the addition of 1% v/v methylated seed oil. Chemistries evaluated were glyphosate (1736 and 3473 g ae ha^{-1}); imazapic (210 g ai); sulfosulfuron (105 g ai); imazapyr (841 g ae) plus glyphosate (848 g ae); thiencarbazone-methyl (267 g ai) plus iodosulfuron-methyl (10 g ai) plus foramsulfuron (101 g ai); indaziflam (50 g ai) plus aminocyclopyrachlor (1401 g ae) plus imazapyr (423 g ae), and clethodim (272 g ai). In the following spring, plant rhizome fresh weight was recorded for all treatments. Additional data collected included tiller counts conducted immediately prior to herbicide application, visual injury following treatment (with 0=no injury and 100=plant death), and spring rhizome viability. At 4 weeks after application, the greatest visual injury was associated with clethodim (13%), and glyphosate injury was <10%. In the spring, no significant differences between treatments were observed for rhizome fresh weight (p=0.87), nor were differences observed for the greenhouse assay of rhizome viability when quantified as emerged shoots (p=0.35) or shoot dry weight (p=0.50). However, a tenfold decrease was observed in the dry biomass of shoots between the untreated control (10 grams) and four of the treatments evaluated: imazapic (0 g), sulfosulfuron (1 g), imazapyr + glyphosate (0 g) and imazapic + glyphosate (1 g). The results of a single trial in 2020 indicate that where significant effects were observed, the inclusion of tiller counts as a covariate always accounted for a significant portion of variability.

Weed Suppression by Winter Annual Cover Crops. Alex J. Hewitt*; Kansas State University, Manhattan, KS (69)

Winter annual cover crops are widely used in agricultural systems around the world during the fallow period when the risk of invasion by weeds is at its highest. Field experiments were conducted at two locations in eastern Kansas to quantify the effects of cover crops on weed emergence patterns. Naturally-occurring weed communities were evaluated from fall 2020 through spring 2021 at site one, and from early to late spring 2021 at site two by documenting weed species and numbers within different cereal and brassica cover crops. The cover crop treatments at site one were 'Elbon' rye (*Secale cereale* L.), 'Rymin' rye (*S. cereale*), 'Surge' triticale (*Triticale hexaploide*), and 'Everest' wheat (*Triticum aestivum* L.), whereas site two utilized mixtures of cereals and brassica species. Two weed species were observed at site one, with over 90% of the observations being henbit (*Lamium amplexicaule* L.) and remaining marestail (*Erigeron canadensis* L.). Site two had seven weed species, with henbit and foxtail barley (*Hordeum jubatum* L.) accounting for over half of the total weeds observed. At site one, 'Rymin' rye had the lowest total weed emergence and the no-cover treatment had the highest. In addition, all the cover crop treatments suppressed the total weed emergence by 18% compared to the no-cover treatment. The rye treatments had a higher initial weed emergence event relative to the triticale, wheat, and no-cover treatments, with over half of the total weeds emerged occurring within the first 12 days after cover crop planting. At site two the broadcast radish (*Raphanus raphanistrum subsp. sativus*) plus rye cover had the lowest total weed emergence and overall, the brassica and mixed cover crop treatments were the most weed suppressive, with only 27% and 22% of the total weed emergence occurring within, respectively. Differences between cover crop treatment and mean weed counts were found to be nonsignificant ($p>0.05$) at both sites. Future research will examine weed emergence patterns within these cover crops in order to identify the most effective weed suppressive cover crops that can be used in integrated weed management programs.

Control Options for Japanese Knotweed Along Roadsides - Initial Results. Joseph Omielan*; University of Kentucky, Lexington, KY (70)

NO ABSTRACT SUBMITTED

Evaluation of Some New Herbicide Products for Use in Missouri Pastures. Haylee E. Schreier*, Travis Winans, Jacob E. Vaughn, Delbert Knerr, Mandy Bish, Kevin W. Bradley; University of Missouri, Columbia, MO (71)

Weeds are the predominate pest found in pastures and they can reduce both the quality and quantity of forage produced. However, many producers are hesitant to apply herbicides in mixed tall fescue and legume pasture due to the likelihood of killing desirable legumes. A new pre-packaged herbicide mixture consisting of florpyrauxifen-benzyl + 2,4-D has been submitted to the Environmental Protection Agency for registration and, if approved, would be the first herbicide available for use in mixed tall fescue and legume pastures that provides broadleaf weed control without eliminating either white clover (*Trifolium repens* L.) and annual lespedeza [*Kummerowia striata* (Thunb.)]. A field experiment was conducted across seven Missouri pastures in 2020 and 2021 to compare the weed control and legume injury following applications of florpyrauxifen-benzyl + 2,4-D, florpyrauxifen-benzyl + aminopyralid, and 2,4-D + aminopyralid. Application occurred between mid-May and early-June each year. Visual weed control and legume injury ratings were taken at regular intervals after treatment. All three herbicide treatments evaluated provided similar control of common (*Ambrosia artemisiifolia* L.) and lanceleaf ragweed (*Ambrosia bidentata* Michx.), tall ironweed [*Vernonia gigantea* (Walter)], and vervain species (*Verbena* spp.) by 3 months after treatment (MAT). However, musk thistle (*Carduus nutans* L.) and blackberry species (*Rubus* spp.) control was lower following applications of florpyrauxifen-benzyl + 2,4-D compared to either florpyrauxifen-benzyl + aminopyralid or 2,4-D + aminopyralid. By 1 week after treatment, white clover was injured 17% by florpyrauxifen-benzyl + 2,4-D compared to 31% injury from florpyrauxifen-benzyl + aminopyralid and 2,4-D + aminopyralid. However, by 3 MAT white clover had almost completely recovered in response to the florpyrauxifen-benzyl + 2,4-D treatment but was completely eliminated by florpyrauxifen-benzyl + aminopyralid and 2,4-D + aminopyralid. Overall, results from these experiments indicate that florpyrauxifen-benzyl + 2,4-D can provide control of several common broadleaf weed species and also preserve white clover stands that are present in mixed tall fescue and legume pastures.

Growing from Strong Roots: NCWSS Members' Vision for the Future. Sarah Lancaster*[1], Erin Haramoto[2], Alyssa Essman[3], Cody Evans[4], Justin Pollard[5], Debalin Sarangi[6], Daniel H. Smith[7], Nader Soltani[8]; [1]Kansas State University, Manhattan, KS, [2]University of Kentucky, Lexington, KY, [3]The Ohio State University, Columbus, OH, [4]Bayer Crop Science, Franlkin, IL, [5]Bayer Crop Science, Lathrop, MO, [6]University of Wyoming, Laramie, WY, [7]University of Wisconsin-Madison, Madison, WI, [8]University of Guelph, Ridgetown, ON, Canada (72)

NO ABSTRACT SUBMITTED

Waterhemp Suppression and Control as a Function of Cereal Rye Biomass. Jose J. Nunes*, Nicholas J. Arneson, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (73)

Cereal rye (*Secale cereale* L.) has become a popular cover crop (CC) in integrated weed management programs to manage troublesome weeds, such as waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer). Despite the benefits of cereal rye as a CC, some aspects of the thresholds that dictate its potential for weed suppression have not yet been fully investigated in the North Central region of the United States. Therefore, this study aimed to determine the required amount of cereal rye biomass to achieve 50% waterhemp suppression (emergence and growth) under field conditions. A dose-response study was conducted on a commercial field naturally infested with waterhemp following a randomized complete block design. Experimental units consisted of 0.9 m by 2.1 m plots and treatments were replicated four times. CC biomass was collected at the anthesis stage from a fall-seeded cereal rye field at Arlington, WI, dried to constant weight at 60ºC, and weighed to meet the following CC rates: 0, 0.6, 1.2, 2.5, 4.9, 7.4, 9.9, and 12.4 Mg ha^{-1}. On June, 02 of 2021, biomass samples were then evenly distributed over the plots' perimeter and covered by a welded wire fence (5 by 10 cm mesh) to prevent the wind from blowing and disturbing the CC mulch. The level of waterhemp suppression (0-100%), emergence (plants m^{-2}), plant height (cm), and biomass (g m^{-2}) were evaluated at 42 days after trial establishment. At the same date, an overhead picture of a 0.25 m^{-2} quadrat (used to collect the variables described above) was taken from each plot, and waterhemp green coverage (%) was estimated using the Canopeo app. Our preliminary results indicate that waterhemp suppression (0.83), emergence (-0.75), plant height (-0.69), green coverage (-0.90), and biomass reduction (0.69) were significantly (p-value <0.005) correlated (correlation in parenthesis) with the increase in CC biomass. Moreover, a biomass level of 7.7 Mg ha^{-1} was estimated to reduce waterhemp emergence by 50%. Waterhemp emergence displayed a striking pattern, given that at biomass rates lower than 2.0 Mg ha^{-1}, CC stimulated emergence instead of suppressing it. This trend has been previously described in the literature, and is likely to occur due to the higher soil moisture content at low CC biomass compared to the absence of biomass in dry years (as 2021 in Wisconsin). Despite the high level of CC biomass required to reduce 50% waterhemp emergence (7.7 Mg ha^{-1}), lower CC amount achieved this threshold, 0.8 Mg ha^{-1} for waterhemp biomass and plant height. Therefore, even at low biomass levels (0.8 Mg ha^{-1}), CC provided waterhemp management benefits by slowing plant development and biomass accumulation which can alleviate competition with the cash crop and reduce the pressure on POST emergence herbicides. Along with future investigations on the effect of waterhemp seed infestation in the soil, these results will potentially elucidate the thresholds that dictate waterhemp suppression by CC biomass. Therefore, producers can have scientific support to set their management plans to achieve the aspired CC biomass for effective waterhemp suppression given their environmental conditions, operations, and waterhemp infestation.

Investigation of Group 4 Herbicide Resistance in Indiana *Amaranthus tuberculatus*. Claudia R. Bland*, Bryan G. Young, William G. Johnson; Purdue University, West Lafayette, IN (74)

Waterhemp (*Amaranthus tuberculatus*) has rapidly become one of the most common and problematic weeds in Indiana soybean production systems. The ability of waterhemp to evolve resistance to many postemergence herbicides poses a serious threat to the use of synthetic auxin herbicides in tolerant soybean varieties. Many populations in Indiana have been reported to have decreased sensitivity to applications of dicamba. Three populations of waterhemp were collected that survived at least one application of dicamba in the field in 2021. These populations plus one sensitive population and were treated with foliar applications of dicamba (0 to 1,120 g ae ha^{-1}). To overcome a hard seed coat, seeds were scarified in a 10% bleach solution and sown into 10x20cm flats containing potting mix. At the 1- to 2-true leaf stage, plants were transplanted into 10 cm^2 pots containing 1:1 mixture of potting mix and field soil. Dicamba treatments were applied when plant heights were between 7 to 12 cm in 140 L ha^{-1} carrier volume. Visual control estimates were taken, 7-, 14-, and 21- days after application (DAA) and aboveground biomass was taken after the 21 DAA rating. Data were analyzed with the non-linear regression via the DRC package in R. GR_{50} and GR_{90} values were calculated from the dried biomass data. All populations showed differing levels of sensitivity to foliar applications of dicamba. Summed up over all rates, the percentage of surviving plants was 76% for population one, 52% for population two, 69% for population three, and 36% for population four, the known sensitive. At ½ labelled rate, 280 g ae/ha, survivorship was 85% for population one, 43% for population two, 71% for population three, and 29% for the sensitive population. At a 1X rate, 560 g ae/ha, survivorship was 100% for population one, 14% for population two, 43% for population three, and 14% for the sensitive population. At the 2X rate, survivorship was 14% for population one, 29% for population two, 29% for population three, and 0% for the sensitive population. From this experiment, population one had the highest survivorship overall. However, plants in population three experienced the most regrowth. The results of this experiment will be used to determine a discriminating rate to use for screening of additional problematic populations.

Emergence Pattern of Horseweed (*Erigeron canadensis*) Populations Across Nebraska.
Ahmadreza Mobli*[1], Maxwel O. Oliveira[1], Liberty Butts[2], Chris Proctor[2], Nevin Lawrance[3], Rodrigo O. Werle[1]; [1]University of Wisconsin-Madison, Madison, WI, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]University of Nebraska-Lincoln, Scottsbluff, NE (75)

Horseweed (*Erigeron canadensis* L.) is a North American indigenous species commonly found in Nebraska cropping systems. Horseweed management is challenging due to prolific seed production, far distance wind seed dispersal, rapid herbicide-resistance evolution, high adaptation to soil conservation strategies, and high competitiveness with crops. Understanding horseweed emergence patterns across Nebraska can contribute to implementing timely and effective tactics to minimize its impact on cropping systems. Therefore, field studies were conducted during the fall and spring of 2016-2017 and 2017-2018 in Lincoln (corn and soybean fields), North Platte (wheat stubble and soybean fields), and Scottsbluff (corn and fallow fields) to estimate the emergence pattern of horseweed accessions collected from Lincoln, North Platte and Scottsbluff, NE. Though the estimated GDD accumulation required for 10, 50, and 90% cumulative emergence slightly varied across accessions and locations, more than 99% of horseweed seedlings from all accessions emerged in the fall across all locations. The density of total emerged seedlings of each accession was highest when established in their site of origin. Our results suggest that late fall and/or early spring is likely the best timing for horseweed management across Nebraska.

Influence of Cover Crops and Higher Loading of Soil Residual Herbicides on Weed Suppression in Soybean. Lucas Oliveira Ribeiro Maia*, William G. Johnson, Bryan G. Young, Eileen J. Kladivko, Shalamar Armstrong, Joshua R. Widhalm; Purdue University, West Lafayette, IN (76)

Cover crops and soil residual herbicides are often recommended to reduce the selection pressure for resistance to POST herbicides. The combination of these methods can provide additive effects on weed suppression, but the interaction of cover crop biomass and soil residual herbicide efficacy requires further investigation. Two field trials were established in the fall of 2019 at the Throckmorton (TPAC) and Pinney Purdue Agricultural Centers (PPAC) to evaluate the influence of cereal rye (*Secale cereale* L.) and crimson clover (*Trifolium incarnatum* L.) cover crops and soil residual herbicides on weed suppression in soybean (*Glycine max* L. Merr). The study was conducted in a split-plot design with cover crop as the main plot and herbicide program as the subplot. The herbicide treatments consisted of: no residual (glyphosate + glufosinate), medium residual (glyphosate + sulfentrazone + *S*-metolachlor), and heavy residual (glyphosate + sulfentrazone + *S*-metolachlor + cloransulam). Additionally, POST applications of glyphosate + glufosinate were made at 4 and 8 weeks after planting (WAP). Cover crop and weed biomass were assessed at two weeks before and 4 WAP, respectively. Herbicide concentrations were determined by collecting soil samples from 0-5 cm at 0, 10, 14, 28, 56, and 112 days after termination (DAT). At PPAC, the application of soil residual herbicides at cereal rye termination provided 77% greater weed suppression (average of 115 kg ha^{-1} between medium and heavy residual treatments) at 4 WAP relative to cereal rye termination without soil residual herbicides (516 kg ha^{-1}). At this site, a 61% reduction in weed biomass at 4 WAP was observed in cereal rye plots that were sprayed with a heavy residual treatment compared to the fallow plots without soil residual herbicides. Similar results were observed at TPAC where termination of cereal rye and crimson clover with the heavy residual program resulted in 86 and 77% reduction in weed biomass at 4 WAP compared to termination without soil residual herbicides. The termination of cereal rye with the heavy residual treatment reduced weed biomass (44 kg ha^{-1}) at 4 WAP by 81% compared to the fallow treatment sprayed with heavy residual treatment (236 kg ha^{-1}). The second POST application at 8 WAP contributed to a complete control of weeds at 16 WAP for all treatments and sites. The cereal rye biomass produced at PPAC (1,857 kg ha^{-1}) was not enough to provide greater weed suppression than the fallow treatment, but it did affect the interception of soil residual herbicides. The initial concentrations of sulfentrazone and *S*-metolachlor were 39 and 33% lower, respectively, in the soil of plots planted with cereal rye relative to the fallow treatment. At 8 WAP, the concentrations of sulfentrazone, cloransulam, and *S*-metolachlor had dissipated by 64, 94, and 95%, respectively, compared to initial concentrations. This research reinforces the current recommendation that soil residual herbicides should be used with cover crops in an integrated weed management approach to provide season-long weed suppression. However, herbicide interception by cover crop residue is likely to occur, so reduced concentrations of soil residual herbicides should be expected.

Seed Destructor: A Harvest Weed Seed Control Method for Managing Herbicide-Resistant Waterhemp in Midwest Soybean Production. Alexis L. Meadows*, Prashant Jha, Avery J. Bennett, Ramawatar Yadav, Edward S. Dearden, Ryan Hamberg, Austin H. Schleich; Iowa State University, Ames, IA (77)

Increasing cases of herbicide-resistant (HR) waterhemp (*Amaranthus tuberculatus* [Moq.] J.D. Sauer) in the Midwest US has created an urgent need to develop integrated weed management (IWM) strategies. Mechanical destruction of weed seeds collected by the combine (a harvest weed seed control method, HWSC) can be used to manage HR weed seeds inputs in soybean. Field experiments were conducted in 2020 and 2021 to evaluate the efficacy of the Redekop™ Seed Destructor in controlling waterhemp seeds retained on the plant at the time of soybean harvest. A randomized complete plot design was used with four replications. Data on percent waterhemp seed retention, combine head loss, and Seed Destructor's destruction efficacy were collected. Percent waterhemp seed retention was quantified by covering female waterhemp plants in the pollination bags (two plants in each plot) at the initiation of the seed development stage. Seed shattering by combine head was assessed by placing two plastic trays (0.7 m wide by 1.2 m long) beneath the female plants during the combine head pass. Finally, to determine the destruction efficacy of the Seed Destructor, eight plastic trays (0.7 m wide by 1.2 m long) were placed behind the combine to collect the threshed material. Percent seed destruction was visually assessed under a microscope. At the time of soybean harvest, 82% of the waterhemp seeds retained on the mother plant. About 10% of the waterhemp seeds retained on the plant were shattered by the combine head at the time of soybean harvest. The Seed Destructor mechanically destroyed about 90% of the waterhemp seeds which entered the combine at the time of soybean harvest. These results indicate that a HWSC method such as Seed Destructors can be used effectively to manage HR waterhemp populations in soybean based cropping systems in the Midwest US.

Weed Suppression Potential Varies Between Cereal Rye Cultivars. Erin Haramoto*, Hanna J. Poffenbarger, Matthew Allen; University of Kentucky, Lexington, KY (78)

Cereal rye (*Secale cereale* L.) cover crops satisfy multiple goals. They rapidly produce ground cover to slow soil erosion and suppress weeds, and their extensive root systems capture excess soil nitrogen after cash crop harvest. With relatively mild winters, Kentucky's producers can plant cereal rye varieties adapted to warmer or cooler temperatures; these may differ in biomass production and ground cover and thus weed suppression. Planting date likely also influences these traits. Our objective was to determine how planting date affected biomass production and weed suppression by warm- and cool-season cereal rye cultivars, and compare these to triticale (x *Triticosecale*) and a no cover crop control. Experiments were conducted over 2018-19 and 2019-20 at the University of Kentucky's North Farm near Lexington, KY. Treatments included six cover crop treatments (warm-season cereal rye cultivars 'Wrens Abruzzi' and 'FL401', cool-season cereal rye cultivars 'Aroostook' and 'Wheeler', triticale 'NE 426GT', and a no cover crop control) planted at two dates (mid-September and late October) in a randomized complete block split-plot design with planting date as the main plot. Cover crop seed was no-till drilled at 67 kg ha^{-1}. Aboveground biomass was sampled prior to termination the following spring, separated into cover crop and weed fractions, dried, and weighed separately. Marestail (*Conyza canadensis* (L.) Cronq.) was also counted at termination. In the first year, across all varieties, early-planted cover crops produced more aboveground biomass than those planted late. Averaged over planting dates, 'Aroostook' and 'Wheeler' produced more aboveground biomass than 'FL401' and 'Wrens Abruzzi'; triticale was intermediate. The cool-season varieties and triticale grew more prostrate and spreading than the warm-season varieties that showed more upright growth. This year experienced mild temperatures through February and early-planted warm-season varieties reached the early jointing stage. A deep and extended cold period then occurred, killing aboveground portions in these plants. These varieties did not experience this damage when planted late as development was more limited. Winter weed biomass and marestail density at termination were similar across all treatments, including the no cover crop control. Most varieties also produced more biomass when planted early in the second year, with the cool-season varieties producing more biomass than the warm-season varieties only if planted early. However, the two warm-season varieties and 'Aroostook' produced more biomass than 'Wheeler' and triticale when planted later. Conditions in the second year, with less severe cold weather, were more favorable for growth of the warm-season varieties. All covers reduced winter weed biomass relative to the no cover control in the second year, but no other treatment differences were detected. Marestail density at termination was reduced in the cool-season varieties and triticale relative to no cover crop and 'Wrens Abruzzi'. Our results highlight the importance of variety in determining cereal rye biomass production. However, contrary to previous research, more cover crop biomass did not always lead to less winter weed biomass. 'Aroostook' performed well across both years and planting dates, while performance of the warm-season varieties was highly weather dependent in the transition zone climate of Kentucky.

Cowpea as a Summer Cover Crop: Effect of Germplasm and Seeding Rate on Weed Biomass. Bautista Garcia Calvo*[1], Erin Haramoto[2], Matthew Allen[2], Sara K. Carter[2], Parmeshwor Aryal[3], Carlene A. Chase[3]; [1]University of Buenos Aires, Buenos Aires, Argentina, [2]University of Kentucky, Lexington, KY, [3]University of Florida, Gainesville, FL (79)

Cowpeas (*Vigna unguiculata* (L.) Walp) are an annual, warm-season legume. They are tolerant of drought, heat, and low fertility, making them an ideal warm-season cover crop. With their large seed size and high growth rates, they can rapidly produce ground cover to protect soil from erosion and smother weeds, and provide a nitrogen source ahead of fall-planted crops. Other beneficial traits found in some cowpea cover crop germplasms include resistance to plant pathogenic nematodes (including *Meloidogyne* spp.) and little or no hardseededness. The overall goal of this project was to develop seeding rate recommendations for three germplasm lines, selected from existing landrace varieties, which lack hardseededness. Our specific objective was to determine the lowest seeding rate for each line that would provide maximum biomass production and weed suppression. Treatments were a fully-factorial combination of the three lines (US-1136, US-1137, and US-1138) and five seeding rates (45, 67, 90, 112, and 135 kg ha^{-1}), with one no cover crop control. Treatments were replicated four times in a field trial in a randomized complete block design. Seed was drilled with a no-till cone planter on July 20, 2021. Overhead photos were taken on August 12 (3 weeks after planting, WAP) and were analyzed using ImageJ to estimate ground cover occupied by the cowpeas. Aboveground weed and cowpea biomass were sampled from one quadrat (0.25 m^2) per plot on September 7 (8 WAP) and September 27 (11 WAP). Weed and cowpea shoots were separated prior to drying and dry biomass was determined separately for each component. Averaged over both sampling dates and all seeding rates, cowpea biomass was higher for US-1136 and US-1138 than for US-1137. Cowpea biomass was similar for the 8 and 11 WAP samplings, indicating that peak biomass occurred at or before 8 WAP. By 8 WAP, US-1137 produced 4050 kg ha^{-1} of biomass, while US-1136 and US-1138 produced 4970 and 5350 kg ha^{-1}, respectively. All cowpea treatments reduced weed biomass relative to the no cover crop control. For US-1136 and US-1137, higher weed biomass was observed at the 67 and 45 kg ha^{-1} seeding rates, respectively, relative to higher seeding rates. US-1138 had similar weed biomass across all seeding rates. Averaged over all seeding rates, the US-1137 produced less ground cover at 3 WAP than the other two germplasms. Averaged over all germplasms, the lower two seeding rates produced less ground cover than higher seeding rates. The 90 kg ha^{-1} seeding rate was suitable for achieving early ground cover, and weed suppression was similar across all germplasms at this seeding rate. This falls within the range of typical cowpea seeding rate recommendations (34-101 kg ha^{-1}). The US-1136 and US-1138 germplasms produced more biomass than US-1137, which could potentially result in higher levels of nitrogen for the next crop. US-1138 produced similar levels of biomass and weed suppression at all seeding rates, so this line should be investigated further if low seeding rates are of interest to producers.

Advancing Dormancy Breaking Techniques in Common Ragweed (*Ambrosia artemisiifolia*). Erin C. Hill[1], Chloe Grabb*[2]; [1]Michigan State University, East Lansing, MI, [2]Michigan State University, Leonard, MI (80)

Mature seeds of common ragweed (*Ambrosia artemisiifolia*) exhibit innate dormancy that has thus far relied on a chilling period (~6-8 weeks outdoors) to overcome. Herbicide resistance bioassay screening of this species can therefore take several months to complete and other types of research can also be delayed. The purpose of this study was to reduce the time it takes to break dormancy to provide results screening to producers and benefit weed science research. Ragweed seeds were stratified for 2, 4, 6, or 8 weeks on sand or paper towel at 5.5C and subsequently placed on filter paper in petri dishes treated with DI water, potassium nitrate, ethephon, gibberellin3, gibberellin a4+7 and 6-benzyl adenine, 6-benzyl adenine, or a mixture of ethephon, gibberellin a4+7 and 6-benzyl adenine. Seeds that were not part of the stratification treatments underwent embryo excision, were treated with sulfuric acid followed by gibberellic acid, or were left untreated before placing in petri dishes. All treatments were stored in the dark at 25C for two weeks, with germination recorded weekly. Preliminary data (excluding the 6 and 8 week stratification treatments) indicates that embryo excision resulted in the highest germination rate (38.7% of initially viable seed), followed by the 2 week paper towel stratification plus the mixture of ethephon, gibberellin a4+7 and 6-benzyl adenine (24.0%). Both treatments were an improvement over the germination rate of the untreated seed (1.0%) and several other treatments. As data continues to be collected, this study will be useful in refining and expediting dormancy breaking measures in common ragweed.

Evaluation of Italian Ryegrass (*Lolium perenne* L. ssp. *multiflorum*) Control Utilizing Soil Residual Herbicides in Kentucky Winter Wheat. Jesse Gray*, Shawn Wood, Travis Legleiter; University of Kentucky, Princeton, KY (81)

Italian ryegrass (*Lolium perenne* L. ssp. *multiflorum*) is one of the most problematic weed species in Kentucky soft red winter wheat hectares. Kentucky wheat growers have traditionally relied on postemergence herbicides such as ALS-inhibitors and ACCase inhibitors for control of this problematic weed. Although, overreliance on both sites of action has led to resistance to the majority of available postemergence herbicides for control of Italian ryegrass, including the increasing presence of pinoxaden resistant ryegrass across the state. The loss of postemergence herbicides for control of this weed species has led to a need to explore alternative herbicide timings and active ingredients. The recent approval of several 24c labels for pyroxasulfone based herbicides for preemergence application in wheat has led to interest in the use of this chemistry for control of Italian ryegrass in soft red winter wheat. An experiment was conducted at the University of Kentucky Research and Education Center in Princeton, KY during the 2020-21 winter wheat growing season. Soft red winter wheat was no-tilled into a field with a known infestation of Italian ryegrass in October 2020. Herbicide programs consisted of a burndown application that included either paraquat or glyphosate with the addition of a pyroxasulfone based residual applied either 14 days preplant, at planting or early postemergence. All treatments received a spring application of pinoxaden plus fenoxaprop. Herbicide treatments were evaluated for visual control following residual applications as well as in the spring and at harvest. Italian ryegrass seed head panicles m^{-2} were taken prior to harvest and wheat yield taken at harvest. The efficacy of pyroxasulfone on Italian ryegrass suppression was dependent on activating rainfall events, with 14 preplant applications having a reduced suppression of ryegrass as compared to at planting and early postemergence applications due to a lack of rainfall at the 14 day preplant timing and adequate and timely rainfall events occurring around the latter two applications. All treatments receiving an application of a pyroxasulfone resulted in at least 87 percent control of Italian ryegrass at the end of the season and significantly reduced seed head production at harvest. The incorporation of pyroxasulfone as a residual herbicide into winter wheat herbicide program increases consistent control of Italian ryegrass and reduces selection pressure on the limited postemergence herbicides remaining for control of this problematic weed.

Investigation of Weed Seed Contamination and Frequency of Herbicide Resistance in Contaminated Sunflower Screenings. Emma A. Mitchell*, Nathan H. Haugrud, Stephanie A. DeSimini, Joseph T. Ikley; North Dakota State University, Fargo, ND (82)

Palmer amaranth (*Amaranthus palmeri*) was first discovered in North Dakota in 2018 and has since been documented in 14 counties. Palmer amaranth has been introduced through various means including cover crop seed and used equipment purchased from other states. At least 6 infestations in 2020 and 2021 were traced to sunflower processing plants that sold screenings to farmers as cattle feed. Samples found these screenings to contain numerous weeds including pigweeds (*Amaranthus* spp.), foxtails (*Setaria* spp.), buffalobur (*Solanum rostratum*), velvetleaf (*Abutilon theophrasti*), cocklebur (*Xanthium strumarium*), common lambsquarters (*Chenopodium album*), and grain sorghum (*Sorghum bicolor*). Pigweed seeds were the most common weed seed contaminant of the sunflower screenings, and subsequent sampling revealed over 2800 pigweed seeds per kg of screenings in 2020, and over 1600 pigweed seeds per kg of screenings in 2021. Seeds were submitted to the National Agricultural Genotyping Center for genetic testing that revealed the seeds to be primarily Palmer amaranth. Three greenhouse experiments were conducted evaluate the presence and prevalence of herbicide resistance in the Palmer amaranth populations found in these screenings. An herbicide mode of action screen was conducted by applied 1x (in parentheses) and 3x ND field rates of glyphosate (1260 g ha^{-1}), imazamox (35 g ha^{-1}), fomesafen (198 g ha^{-1}), atrazine (560 g ha^{-1}), mesotrione (105 g ha^{-1}), tembotrione (92 g ha^{-1}), glufosinate (656 g ha^{-1}), dicamba (560 g ha^{-1}), and 2,4-D (560 g ha^{-1}). Two additional resistance screens were conducted by spraying 112 plants with 1,260 or 35 g ha^{-1} of glyphosate or imazamox, respectively. Leaves from each plant that were tested for glyphosate resistance were genetically tested for markers corresponding to resistance. Results from the herbicide mode of action screen found the population to be resistant to field rates of glyphosate with 55% of tested plants surviving, imazamox with 77% survival, atrazine with 64% survival, mesotrione with 65% survival, and 2,4-D with 35% survival. The results from the 112-plant resistance screens found 41% of plants survived glyphosate 21 DAT, 89% of which were genetically identified to have amplification of EPSPS as a resistance mechanism. The remaining 11% that survived had normal copy numbers of EPSPS, indicating another mechanism of glyphosate-resistance is present in the population. Of the plants screened for imazamox resistance, 81% of plants survived 21 DAT. Due to the nature introduction through sunflower screenings from a sunflower processing plant, these new Palmer amaranth populations are likely a combination of numerous populations from across the sunflower growing regions of the US, leading to the highly variable response to herbicides. Further research is needed to characterize the herbicide resistance mechanisms within the population and to determine the number of sites of action of herbicide resistance within individual plants.

Long-Term Management of Herbicide-Resistant Waterhemp Seedbank in Corn-Soybean Rotations. Ramawatar Yadav*, Prashant Jha, Avery J. Bennett, Alexis L. Meadows, Austin H. Schleich; Iowa State University, Ames, IA (83)

In response to the mounting cases of multiple herbicide-resistant (MHR) waterhemp (*Amaranthus tuberculatus* [Moq.] J.D. Sauer) populations in Iowa, field experiments were conducted to design multi-tactic strategies to manage this weed. The study spanned over three years in a corn-soybean-corn rotation during 2019 to 2021. Effect of two corn herbicide programs (HP) on *A. tuberculatus* seed inputs was tested in 2019. Effect of 2019 seed inputs, cereal rye cover crop (terminated at soybean planting), and narrow (38 cm)- vs. wide (76 cm)-row soybean on *A. tuberculatus* density and seed production was tested in soybean in 2020. The cumulative effect of weed control diversity on *A. tuberculatus* density was tested in the following corn (with the same HP) in 2021. In 2019, a marginal herbicide program (MHP) comprising of two sites-of-action herbicides provided only 35% control of glyphosate-resistant *A. tuberculatus*, compared with =97% control by an aggressive herbicide program (AHP) with three herbicide sites-of-action. In 2020 soybean, no new seed inputs from the previous year's corn (AHP) reduced *A. tuberculatus* density by >55% compared with seed inputs from MHP. Cover crop or narrow-row soybean alone reduced *A. tuberculatus* density by at least 13% compared with the no cover crop or wide-row soybean. Cumulatively, cover crop and narrow-row soybean reduced *A. tuberculatus* density and seed production by =40% compared with no cover crop and wide-row soybean. In 2021 corn, MHP plots had 80% higher *A. tuberculatus* density than AHP plots. Furthermore, MHP plots which included cover crop and narrow-row soybean in 2020 had 40% higher *A. tuberculatus* density in 2021 than plots with no cover crop and wide-row soybean; however, this difference was not evident in AHP plots. These results indicate that waterhemp should be managed aggressively in corn with multiple effective herbicide sites of action to prevent seed bank inputs. Additionally, cultural strategies such as cereal rye cover crop and reduced row spacing should be incorporated in the soybean phase of the rotation to mitigate the herbicide-resistant *A. tuberculatus* seed bank at a cropping systems level.

Comparative Analysis of Weedy and Grain *Amaranthus* Species Reveals Mobilome Contributing to Genome Diversity. Damilola A. Raiyemo*[1], Jacob S. Montgomery[2], Nathan D. Hall[3], Eric L. Patterson[4], Patrick Tranel[1]; [1]University of Illinois, Urbana, IL, [2]Colorado State University, Fort Collins, CO, [3]Auburn University, Auburn, AL, [4]Michigan State University, East Lansing, MI (84)

The genus *Amaranthus* is a diverse plant group consisting of weedy species, crops, and wild relatives. *Amaranthus tuberculatus* (Moq) Sauer, *Amaranthus palmeri* (S.) Watson and *Amaranthus hybridus* L. are three agronomically important weeds in North America that have evolved resistance to herbicides from several modes of action. The genomes of these weed species differ considerably in size. The causes of those differences are investigated here. Through a series of whole-genome comparative analyses, we report that *A. tuberculatus* has had its genome inflated by retrotransposons, especially the long terminal repeat *Gypsy* (17.01% of the genome, over twice that of *A. palmeri*, 7.79%, and *A. hybridus*, 8.66%). We identified a similar increase in the long interspersed nuclear elements LINE/L1 between the two dioecious species, *A. tuberculatus* and *A. palmeri*. Furthermore, approximately 20% of the genes in *A. palmeri* are retained from a whole genome duplication event common to all species, compared to ~14% in *A. tuberculatus* and ~16% in *A. hybridus*. Analysis of nonsynonymous and synonymous mutation rates identified seven genes putatively under positive selection in these three weeds when compared to the crop relative *A. hypochondriacus*. One interesting gene was annotated as dehydration-responsive element-binding protein 2H (DREB2H), which is known to play a role in drought tolerance in plants. Taken together, our findings highlight the major factors that contribute to the genome-size variation in these closely related weeds and highlight genomic changes that may be contributing to the adaptability and persistence of these plant species as notorious weeds.

Multiple Herbicide Resistance in Wisconsin Waterhemp (*Amaranthus tuberculatus*) Accessions. Felipe de Andrade Faleco*, David E. Stoltenberg, Mark J. Renz, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (85)

Waterhemp [*Amaranthus tuberculatus* (Moq.) Sauer] has become a steadily increasing concern in WI. Currently, waterhemp herbicide resistance in WI has been confirmed to inhibitors of ALS (imazethapyr), EPSPS (glyphosate), and PPO (fomesafen and lactofen). A comprehensive WI state-wide assessment of waterhemp response to a diverse group of herbicide SOA inhibitors has not been conducted. Consequently, our objective was to compare the efficacy of POST and PRE herbicides commonly used in corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] on a state-wide collection of waterhemp accessions. Greenhouse experiments were conducted with more than 80 accessions from 27 WI counties. Postemergence treatments were imazethapyr, dicamba, 2,4-D, atrazine, glyphosate, glufosinate, fomesafen, and mesotrione at the 1× and 3× label doses. Preemergence treatments were atrazine, metribuzin, fomesafen, S-metolachlor, and mesotrione at the 0.5×, 1×, and 3× label doses. One hundred, 93, 17, 16, and 3% of the accessions were classified resistant (= 50% survivorship) to imazethapyr, glyphosate, 2,4-D, atrazine, and dicamba POST at the 1× dose, respectively. Ninety-eight, 87, and 5% of the accessions were resistant to imazethapyr, glyphosate and atrazine POST at the 3× dose. No accession was resistant to 2,4-D or dicamba POST at the 3× dose, or to glufosinate, fomesafen, or mesotrione POST at either dose. Atrazine, fomesafen, S-metolachlor, and mesotrione PRE at the 0.5× dose were classified ineffective (< 90% plant density reduction) on 93, 27, 3, and 3% of the accessions. Atrazine and fomesafen PRE at the 1× dose were ineffective on 83 and 3% of the accessions, respectively. Atrazine PRE at the 3× dose was ineffective on 45% of the accessions. Fomesafen PRE at the 3× dose, S-metolachlor and mesotrione at the 1× and 3× doses, and metribuzin at either dose were effective on all accessions. Our results suggest that imazethapyr and glyphosate POST are ineffective for waterhemp control in WI, inferring resistance. One of the most concerning accession exhibited multiple resistance to imazethapyr + glyphosate + atrazine + 2,4-D. Our results also suggest that atrazine PRE is ineffective for waterhemp control in WI on silty clay loam soils. Proactive resistance management, which incorporates the use of effective POST and PRE herbicides as part of an integrated weed management, is fundamental for waterhemp management in WI and beyond.

Relationship of Soil Properties and the Spatial Distribution of Weed Seedbanks. Rose V. Vagedes*, Bryan G. Young, William G. Johnson; Purdue University, West Lafayette, IN (86)

Weed seedbanks are not uniformly distributed across an agricultural field, yet the major drivers influencing spatial differences of weed seedbanks have largely been left to anecdotal interpretations. Data analysis on the heterogeneity of weed seedbanks has commonly been conducted with various numeric distribution parameters. Results from these types of analyses are limited to a single numerical value that describes whether or not clustering is present within the area of interest. Additionally, limited research has been conducted to document the spatial correlation of various weed seedbank characteristics and field soil properties such as clay content, organic matter content, pH, cation exchange capacity (CEC), and electrical conductivity. The objective of this study was to document the spatial variability of weed seedbank characteristics within four commercial fields in Indiana and attempt to correlate those characteristics with the aforementioned soil properties. In the spring of 2021, 60 soil samples were collected from each field in a stratified, random sampling pattern. After six weeks of cold storage at 4 C, weed seedbank samples were submitted to three grow-out periods under greenhouse conditions, each lasting four weeks and separated by a 2-day period for drying and mixing the samples. To determine the presence of clustering of weed seedbank abundance, species richness, and individual weed species density, data were evaluated using spatial autocorrelation. The locations of clusters within a field were identified using a geostatistical method known as ordinary kriging. When comparing the relationship of the total abundance of broadleaf species with various soil properties, organic matter content explained between 10% to 24% of this variation in three of the four fields. Additionally, up to 26% and 45% of the variation in total weed seedbank and broadleaf species abundance, respectively, was explained by the combined effects of clay content and organic matter for three fields. The five most prevalent species across all fields were waterhemp (*Amaranthus tuberculatus*), carpetweed (*Mollugo verticillate)*, fall panicum (*Panicum dichotomiflorum*), goosegrass (*Eleusine indica*), and common purslane (*Portulaca oleracea*). Carpetweed was the only weed species to show significant clustering and a moderate correlation to one of the soil properties analyzed in this study (organic matter content). No soil property consistently correlated with weed seedbank distribution, abundance, diversity, or richness for all fields.

Optimizing Timings of Dicamba and Glufosinate for Control of Glyphosate-resistant Palmer Amaranth in XtendFlex Soybeans. Monica R. Marrs*[1], Vipan Kumar[2], Anita Dille[1], Augustine Obour[2]; [1]Kansas State University, Manhattan, KS, [2]Kansas State University, Hays, KS (87)

The widespread evolution of glyphosate-resistant (GR) Palmer amaranth (*Amaranthus palmeri* S. Watts.) is an increasing management challenge for soybean producers. Recent commercialization and rapid adoption of glyphosate/dicamba/glufosinate-resistant (GDG-R) soybeans (XtendFlex) allows growers to use POST applications of dicamba and glufosinate for in-season control of GR Palmer amaranth. However, the extended period of Palmer amaranth emergence makes it harder to decide on optimum timing of these POST herbicide applications. The main objective of this research was to optimize the timings of POST applied dicamba and glufosinate for GR Palmer amaranth control in GDG-R soybeans under no-tillage dryland conditions. To meet this objective, two separate field experiments were conducted in 2021 growing season at Kansas State University Agricultural Research Center in Hays, KS: one experiment was drilled at 25 cm row spacing and second experiment was planted at 76 cm row spacing. The study site had a natural seedbank of GR Palmer amaranth population. For each experiment, the GDG-R soybean variety 'AG37XF1' was planted on May 24 at a population of 156,900 seeds ha^{-1}. Each experiment was comprised of four POST herbicide treatments: a) Nontreated, b) Dicamba applied at 560 g ae ha^{-1} alone, c) dicamba followed by (*fb*) glufosinate at 603 g ae ha^{-1} plus acetochlor at 1260 g ae ha^{-1} (two sequential 10 days apart), and d) dicamba plus acetochlor *fb* glufosinate (two sequential 10 days apart) applied at three different timings: first timing at 15 days after soybean drilling/planting, second timing at 25 days after soybean drilling/planting, and third timing at 35 days after soybean drilling/planting. Each experiment was conducted in a randomized complete block design with factorial arrangement of treatments (herbicide programs by application timings) with 4 replications. Data on soybean injury and percent visual control of GR Palmer amaranth were collected at 10 days interval after first POST application. Two 0.25 m^2 quadrats were used to estimate Palmer amaranth density and aboveground biomass at each evaluation timings. All data were subjected to analysis of variance (ANOVA) using PROC Mixed in SAS. Results indicated that in 76 cm row soybeans, dicamba applied at 25 days after planting *fb* a sequential treatment of glufosinate plus acetochlor provided excellent control (100% end of season control), reduced density and biomass of GR Palmer amaranth by 0% to 98% as compared to nontreated check. Regardless of planting methods, a single POST treatment of dicamba provided up to 89% control of GR Palmer amaranth. Altogether, these results suggest that two-pass POST herbicide programs can provide an excellent, season-long control of GR Palmer amaranth in GDG-R soybeans.

Cover Crops, Weeds, and Residual Herbicides: Winners and Losers. Ethan Ley*; University of Minnesota, St. Paul, MN (88)

NO ABSTRACT SUBMITTED

Evaluation of Italian Ryegrass (*Lolium perenne* L. ssp. *multiflorum*) Control Utilizing Soil Residual Herbicides in Kentucky Winter Wheat. Jesse Gray*, Shawn Wood, Travis Legleiter; University of Kentucky, Princeton, KY (89)

Italian ryegrass (*Lolium perenne* L. ssp. *multiflorum*) is one of the most problematic weed species in Kentucky soft red winter wheat hectares. Kentucky wheat growers have traditionally relied on postemergence herbicides such as ALS-inhibitors and ACCase inhibitors for control of this problematic weed. Although, overreliance on both sites of action has led to resistance to the majority of available postemergence herbicides for control of Italian ryegrass, including the increasing presence of pinoxaden resistant ryegrass across the state. The loss of postemergence herbicides for control of this weed species has led to a need to explore alternative herbicide timings and active ingredients. The recent approval of several 24c labels for pyroxasulfone based herbicides for preemergence application in wheat has led to interest in the use of this chemistry for control of Italian ryegrass in soft red winter wheat. An experiment was conducted at the University of Kentucky Research and Education Center in Princeton, KY during the 2020-21 winter wheat growing season. Soft red winter wheat was no-tilled into a field with a known infestation of Italian ryegrass in October 2020. Herbicide programs consisted of a burndown application that included either paraquat or glyphosate with the addition of a pyroxasulfone based residual applied either 14 days preplant, at planting or early postemergence. All treatments received a spring application of pinoxaden plus fenoxaprop. Herbicide treatments were evaluated for visual control following residual applications as well as in the spring and at harvest. Italian ryegrass seed head panicles m^{-2} were taken prior to harvest and wheat yield taken at harvest. The efficacy of pyroxasulfone on Italian ryegrass suppression was dependent on activating rainfall events, with 14 preplant applications having a reduced suppression of ryegrass as compared to at planting and early postemergence applications due to a lack of rainfall at the 14 day preplant timing and adequate and timely rainfall events occurring around the latter two applications. All treatments receiving an application of a pyroxasulfone resulted in at least 87 percent control of Italian ryegrass at the end of the season and significantly reduced seed head production at harvest. The incorporation of pyroxasulfone as a residual herbicide into winter wheat herbicide program increases consistent control of Italian ryegrass and reduces selection pressure on the limited postemergence herbicides remaining for control of this problematic weed.

Effect of Plant Growth Regulator Herbicides on Native Plant Species. Samuel N. Ramirez*, Karla L. Gage; Southern Illinois University, Carbondale, IL (90)

Native plants provide shelter and food for a multitude of pollinators, including butterflies, bees, and other insects, birds, and mammals. These plants are adapted to the local climate and edaphic conditions and provide ecosystem services, such as soil carbon capture and water filtration. The establishment of native plants in pollinator conservation plantings on agricultural lands has been promoted through government-based landowner incentive programs, in an attempt to slow population declines of pollinators. Many of these conservation plantings are near agricultural production fields where plant growth regulator herbicides, such as dicamba and 2,4-D, are used. The sensitivity of many of these species to drift rates of plant growth regulator herbicides is not known. Therefore, this study investigates the sensitivity of six common Illinois native plant to low rates of dicamba and 2,4-D. The species tested were butterfly milkweed (*Asclepias tuberosa* L.), perplexed ticktrefoil (*Desmodium perplexum* B.G. Schub.), cup plant (*Silphium perfoliatum* L.), compassplant (*Silphium laciniatum* L.), rattlesnake master (*Eryngium yuccifolium* Michx.), and Virginia mountain mint (*Pycnanthemum virginianum* (L.) T. Dur. & B.D. Jacks. ex B.L. Rob. & Fernald). Plants were treated with dicamba and 2,4-D at 0, 0.0005x, 0.0025x, 0.0125x, 0.0625x, and 0.3125x of field use rates. There were ten replicates of each herbicide rate and plant species combination. Plant response was assessed through visual ratings and plant height over time and final biomass measures at 35 days after application. Due to variable plant sizes between experimental runs and between herbicide treatment groups, species and herbicide were analyzed separately using one-way ANOVA to test for differences in response to herbicide rate by species. No plant mortality was observed for these species for any of these herbicide rates. There were significant differences in total biomass accumulation in response to rates of one or both herbicides, except perplexed ticktrefoil, which was not sensitive to either herbicide up to the 0.3125x rate. *Silphium* spp. (cup plant and compassplant) had significant biomass reduction at the 0.3125x rate for dicamba and 2,4-D. Butterfly milkweed, rattlesnake master, and Virginia mountain mint had significant biomass reduction at the 0.3125x rate for 2,4-D only. This study demonstrates the differential effects that low rates of these two plant growth regulator herbicides can have on native plant species in a greenhouse setting. These results provide baseline data on plant sensitivity which suggests the potential for a species shift in native plant communities in agricultural settings in response to plant growth regulator drift.

Effects of Cropping Practices on the Weed Seedbank. Mackenzie R. Trader*[1], Karla L. Gage[1], Karl W. J. Williard[1], Jon E. Schoonover[1], Randy McElory[2], Amir Sadeghpour[1]; [1]Southern Illinois University, Carbondale, IL, [2]Bayer Crop Science, Farina, IL (91)

Herbicide resistance is on the rise in the Midwest, creating a challenge for farmers to effectively manage weeds in commercial crop production systems. The primary focus has been chemical control of weeds during the growing season to minimize loss and maximize yield; however, while this may be an economical short-term solution, integrated weed management solutions are needed. Long-term, multifaceted cropping practices that prevent weed emergence and weed seed production need to be the focus for successful weed control. To examine changes and differences in distribution and composition between individual species in the weed seedbank in response to cover crop rotations and tillage, a long-term field study was established in 2013 using a split-plot design with three crop rotation systems: 1) corn (*Zea mays* L.) – cereal rye (*Secale cereale* L.) – soybean (*Glycine max*) – hairy vetch (*Vicia villosa* R.) [CcrShv], 2) corn-cereal rye-soybean-oats + radish (*Avena sativa* L. + *Raphanus sativus* L.) [CcrSor], and 3) corn-no cover crop-soybean-no cover crop [CncSnc], and two tillage treatments: conventional tillage and no-till. Seeding rates for cereal rye, hairy vetch, and oats + radish were 87, 28, and 39 kg ha^{-1}, respectively. Each tillage and crop rotation were replicated three times. To assess the weed community present in the seedbank, two soil cores with a volume of 120 cm^3 (r=2.26 cm; h=7.5 cm) were taken per sub-plot in the fall of 2019 after harvest. Using these samples, a soil grow-out was conducted in the greenhouse where emerged weeds were counted and identified, then removed from the sample. A total of 27 species were found in the weed seedbank. The most common species in order of greatest to least abundance in at least 10 percent of the plots were: henbit (*Lamium amplexicaule*), Draba spp., terrestrial starwort (*Callitriche terrestris*), mouseear chickweed (*Cerastium vulgare*), common chickweed (*Stellaria media*), small flower buttercup (*Ranunculus abortivus*), carpetweed (*Mollugo verticillata*), Virginia rockcress (*Sibara virginica*), annual bluegrass (*Poa annua*), and Veronica spp. Permutational Multivariate Analysis of Variance (PERMANOVA) suggested an interactive effect of tillage and cropping system on the weed seedbank community. However, Permutational Analysis of Multivariate Dispersions (PERMDISP) suggested that there was also significant variability within the tillage treatments. Weed seedbank diversity measures were analyzed, and richness differed by cropping system; systems with hairy vetch had lower species richness than systems with oats and radish or no cover crop. Some species were differentially affected by tillage or crop, but there were no interactive effects of tillage and crop on any of the most abundant species. These data suggest that cropping systems that incorporate cover crops and tillage may have the ability to alter the weed seedbank over time.

Targeted Weed Management: Challenges and Opportunities. Thiago H. Vitti*[1], Rodrigo Werle[2], Bruno Canella Vieira[2], Christopher Proctor[1], Isaac Harrison Barnhart[3], Anita Dille[3], Greg Kruger[4]; [1]University of Nebraska Lincoln, Lincoln, NE, [2]University of Wisconsin-Madison, Madison, WI, [3]Kansas State University, Manhattan, KS, [4]University of Nebraska Lincoln, North Platte, NE (92)

Weeds compete for water, sunlight, nutrients, space and, when uncontrolled, may result in yield losses up to 100%. Weed management represents one of the greatest challenges in modern row-crop systems. While weeds are commonly managed using broadcasted preemergence and postemergence herbicides, herbicide resistance, environmental concerns, and increasing input costs highlight the need for alternative weed management approaches. While site-specific weed management is not a new concept, technological advances such as sensors (e.g., UAS and sprayer mounted), complex algorithms, and machine learning now provide accurate geo-referenced weed maps and are anticipated to advance toward crop/weed differentiation and weed species identification. These weed-specific maps not only provide opportunity for precise site-specific weed control strategies, but may also improve the timeliness of control strategies as the ability to rapidly generate these maps continues to improve. Site-specific weed data are being used to develop equipment for targeted herbicide applications (aka spot spraying). Early development of spot sprayer technology is reported to reduce herbicide applied by up to 75%. There is also potential for integration of mechanical tools that rely on tilling, pulling, lasers, flaming, electricity, etc. for targeted weed management. A brief review of site-specific weed management and the potential for such technology will be presented. The poster will explore how targeted weed management strategies might influence the agronomics, economics, and environmental impact of row-crop systems adopting such technology.

Impact of Elevated CO_2 Levels on C3 (*Chenopodium album*) and C4 (*Amaranthus palmeri*) Weed Growth. Megan L. Williams*[1], Anita Dille[2]; [1]University of Virginia, Washington, DC, [2]Kansas State University, Manhattan, KS (93)

Changing global average temperatures and precipitation patterns are expected to affect crop productivity, thus it is important to understand how weed-crop competition will react to rising CO2 levels. Due to differences in CO2 assimilation frameworks, C3 and C4 plants are expected to react differently, with C3 increasing CO2 assimilation and C4 showing no change. This study's objective was to determine how biomass and leaf area in C3 and C4 invasive weeds respond to increased CO2 supply in the absence of other limiting factors. *Amaranthus palmeri* (C4) and *Chenopodium album* (C3) were grown at predicted potential atmospheric CO2 concentrations (means: control= 475, elevated 1= 602, and elevated 2= 676 ppm) over 31 days. Seventy plants of each species were put in each of the three growth chambers set at these CO2 concentrations. Every week for five weeks, 12 plants of each species were removed from each growth chamber and were assessed. Total leaf area (TLA) was measured using a LI-3100C area meter. Total above ground biomass (TAGB) was dried and weighed. Compared to the control, A. palmeri TLA initially increased with both elevated CO2 levels, but by week 4 rate of increase slowed while leaf area continued to increase for the control CO2 level, with week 5 mean TLA being 230 cm^2 lower 148 cm^2 lower than the control in elevated 1 and elevated 2 conditions, respectively. Potential explanation for this trend is emergence of reproductive material diverting biomass production from leaves to flowers. Under elevated CO2, *A. palmeri* TAGB increased at a higher rate over time compared to the control, with week 5 mean TAGB being 2.19 g and 1.74 g per plant higher than the control in elevated 1 and elevated 2 conditions, respectively. Compared to the control, *C. album* both TLA and TAGB increased at a higher rate, with week 5 mean TAGB being 1.66 g and 0.92 g per plant higher than the control in elevated 1 and elevated 2 conditions, respectively, and week 5 mean TLA being 79 cm2 higher but 293 cm2 lower than the control in elevated 1 and elevated 2 conditions, respectively. Contrary to predictions, both species clearly responded to elevated CO2 with significantly more leaf area and biomass; despite *A. palmeri* being a C4 plant, there still was an effect of elevated CO2 on its growth. Effects were similar in both species but potentially were still relatively greater in the C3 plants. For TAGB, two way ANOVA tests showed there was no significant interaction between species and CO2 level for 4 out of the 5 weeks. For TLA, the two way Anova tests showed there was a significant interaction between species and CO2 level. Overall, these data suggest both C3 and C4 weed species experience faster rates of growth in early life under elevated atmospheric CO2 conditions. Future studies should involve whether C4 crops respond to elevated CO2 in the same way as C4 weeds in order to predict how the competition dynamic will change over time.

Emergent Cohort Dynamics of Palmer Amaranth on Growth and Flowering. Ethan C. Denson*, Anita Dille; Kansas State University, Manhattan, KS (94)

Palmer amaranth (*Amaranthus palmeri*) is an invasive dioecious plant that causes widespread economic losses due to overcrowding and competition with desired crops. Because Palmer amaranth is dioecious, it allows for more genetic crossing among populations. This ability, combined with the reproductive potential to release up to 400,000 seeds per plant, its fast growth, and drought tolerance, means that Palmer amaranth can adapt and colonize many different environments. Therefore, the goal of this study is to document late-season Palmer amaranth emergence, growth, and time to flowering, in order to compare the demography of male and female plants. To conduct this observational study, four plots, measuring 1.5 by 3 meters, were selected in a soybean field in Gypsum, KS. Five PVC rings, measuring about 20 centimeters in diameter, were randomly placed in each plot, for a total of 20 rings. Every week, plant density was recorded, and measurements were taken of six plants in each ring to document the average tallest and shortest plant, widest and narrowest canopy width, as well as the date of flowering and final seed production for each emergent flush in relation to the gender of the plants in each ring. A total of three flushes were documented, each flush being a two-week interval starting July 21, 2021. More male Palmer amaranth plants emerged in flush one than in flush three. Male plants slowed their growth after initiating flowering, as it reached its reproductive goal and released pollen. Female plants continued to grow and develop seed until the plant matured and terminated. In general, male Palmer amaranth emerges and began to mature before the female plants. This suggests the potential to study control measures that slow the development of male Palmer amaranth plants in order to reduce its reproductive potential.

Barriers to Adoption: Farmer Collaborators Use Inter-seeded Winter Wheat Practices as a Sustainable Approach for Suppressing Common Waterhemp in Soybean. Madison R. Decker*, Karla L. Gage, Ronald F. Krause; Southern Illinois University, Carbondale, IL (95)

Amaranthus species are some of the most troublesome weeds for Midwestern soybean producers due to the selection of biotypes resistant to multiple herbicide site of action groups. Today, there is documented common waterhemp resistance to seven herbicide site of action groups in Illinois and three in Indiana. Furthermore, documented resistance in Palmer amaranth has been reported in three herbicide site of action groups in Illinois and one in Indiana. Due to the decrease in the development of new herbicide sites of action, it is imperative that alternative control methods are investigated. Therefore, research was conducted in collaboration with growers in the 2021 growing season in three separate locations to evaluate the use of inter-seeded winter wheat on common waterhemp suppression in soybean. Trials were implemented in three locations: Red Bud, Illinois in Randolph County, Salem, Illinois in Marion County, and Washington, Indiana in Daviess County to investigate this integrated weed management (IWM) program. Collaborative research with growers gives us the opportunity to obtain feedback on the practical implementation of this program while allowing growers to apply this IWM practice on their farm. Each location was given guidance on the goal of the program, a treatment list, and information on how previous inter-seeded winter wheat research has been implemented at Southern Illinois University. Furthermore, growers were asked to implement their trial in a method they thought would be most practical and effective while using their own equipment. Results from this 2021 research indicate that winter wheat inter-seeded in soybean reduced the number of emerged *Amaranthus* species when compared to the soybean-only post-emergence only treatment 0 days after POST (DAP). Additionally, the use of winter wheat inter-seeded in soybean reduced the height of *Amaranthus* species 0 DAP when compared to the soybean-only pre-emergence followed by post-emergence and the soybean-only post-emergence only treatments. These results suggest that due to the reduced number and height of *Amaranthus* species, inter-seeded winter wheat combined with an herbicide program may provide an effective weed control management practice for the control of *Amaranthus* species.

Evaluation of Fall-Applied Burndown and Residual Herbicides for Winter Annual Weed Control. Daniel Beran*[1], Bob Bruss[2]; [1]Nufarm Americas, Eldora Us, IA, [2]Nufarm Americas, Morrisville, NC (96)

Fall-applied herbicide applications are a common practice for many producers in the Midwest in no-till corn (*Zea mays* L.) and soybean (*Glycine max* L. Merr.) production systems. Fall-applied herbicides can control a wide range of winter annual weeds and provide a weed free seedbed in fields slated for early-spring planting. Standard fall herbicide programs that utilize glyphosate and 2,4-D generally control most emerged winter annuals. Winter annual weeds with extended germination windows, such as horseweed/marestail (*Erigeron canadensis* L.), may be more effectively controlled with tank mixtures of residual chemistries. Field studies were conducted in fall 2019 and 2020 across several states to evaluate the efficacy of fall-applied herbicides, and the effect of residual chemistries. Treatments evaluated in the experiments included glyphosate plus 2,4-D applied alone and in combination with flumioxazin, flumioxazin + metribuzin, and rimsulfuron + thifensulfuron. At the trial conducted in Iowa, November applications of all treatments provided similar control of marestail through mid-April. In contrast, treatments that included flumioxazin at 28 g ai ha^{-1} or 43 g ai ha^{-1} provided greater control when rated in mid-May. Similarly, at the Missouri location, October-applied treatments that included flumioxazin or rimsulfuron + thifensulfuron provided greater control of marestail, henbit (*Lamium amplexicaule* L.), and corn buttercup (*Ranunculus arvensis* L.) when rated in mid-April. In contrast at the Indiana, Illinois, and Ohio locations, glyphosate + 2,4-D treatments provided similar control of marestail as those that contained residual active ingredients. In the Arkansas location, fall treatments that included flumioxazin, flumioxazin + metribuzin, and rimsulfuron + thifensulfuron provided greater control of henbit, cutleaf eveningprimrose (*Oenothera laciniata* Hill), chickweed (*Cerastium* sp.), and cut-leaf geranium (*Geranium dissectum* L.) than glyphosate + 2,4-D alone. The results from these locations indicate that the use of residual herbicides that include flumioxazin and rimsulfuron + thifensulfuron in the fall can increase overall control but results are dependent on weed spectrum and environmental conditions.

Impact of Soil and Cover Crop Management Strategies on the Deposition and Fate of Preemergence Herbicides in Soybean Cropping Systems. Jose J. Nunes*, Nicholas J. Arneson, Ryan P. DeWerff, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (97)

Cover crops (CC) and PRE-emergence herbicides (PREs) have become common practices to manage herbicide-resistant weeds in soybean production systems. Nonetheless, adopting these two practices in combination raises concerns regarding the herbicide fate in the soil, given that the CC biomass can intercept the herbicide spray solution preventing it from reaching the soil. Therefore, this study investigated the impact of soil and CC management practices on the spray deposition and fate of soil-applied herbicides in soybean cropping systems to better understand the dynamics between CC and PREs. A field experiment was conducted in 2020 and 2021 following a randomized complete block design with four replications. Treatments consisted of two cereal rye (*Secale cereale* L.) CC termination practices deployed prior to soybean planting (glyphosate [1,260 g ae ha^{-1}] and roller-crimper + glyphosate) and two standard soil management practices (conventional tillage and no-till). Soybean was the previous crop in both years. The spray solution deposition was assessed by placing water-sensitive paper cards on the soil surface before spraying the PREs (sulfentrazone [153.2 g ai ha^{-1}] + S-metolachlor [1,379.1 g ai ha^{-1}]). Once the PREs were sprayed (tractor-mounted sprayer, nozzle 11002AIXR, speed 6.4 km h^{-1}, pressure 193 kPa, and carrier volume 93.5 L ha^{-1}), the paper cards were retrieved, photographed, and the number of spray droplets (droplets per card) and spray coverage (%) were estimated using the computer program "Gotas". Additionally, soil samples were collected to analyze the sulfentrazone and S-metolachlor concentration in the soil (0-7.5 cm depth) 25 days after treatment (DAT). Results showed that presence of stubble (no-till treatment) and CC (glyphosate and roller-crimper + glyphosate treatments) reduced the number of spray droplets that reached the soil surface and the spray coverage compared to conventional tillage at PRE application. Moreover, the higher the amount of CC biomass at termination, the larger was the reduction in the number of droplets and spray coverage. For instance, in 2020, when a CC biomass of 5.2 Mg ha^{-1} was recorded at termination, the CC treatments glyphosate and roller-crimper + glyphosate resulted in an average of 41% and 63% reduction in the number of droplets and spray coverage, respectively, compared to 81% and 90% reduction in 2021, when the CC biomass was 12.2 Mg ha^{-1}. As for the herbicide concentration in the soil 25 DAT, the presence of CC at PRE application reduced the concentration of S-metolachlor and sulfentrazone by 60% and 38%, respectively, compared to conventional tillage in the first experimental run (2020). Therefore, our findings indicate that no-till residue and CC biomass can affect (i.e., reduce spray coverage and number of droplets) the spray deposition and fate of PRE herbicides compared to conventional tillage. Producers should be aware of this interaction, which will likely result in lower amount of PRE herbicides reaching the soil. Future research is required to evaluate the CC impact on reducing the PRE concentration in the soil with the weed suppression benefit of CC under high infestation of troublesome weeds and different environmental conditions.

Fall-Seeded Cereal Rye and Narrow Soybean Row Widths Improve Horseweed Management. Justine L. Fisher*, Christy Sprague; Michigan State University, East Lansing, MI (98)

Alternative management strategies are needed for herbicide-resistant horseweed (*Erigeron canadensis* L.) in soybean. Integrating cover crops with soybean planted in narrow rows may provide the alternatives needed to improve control and reduce selection pressure on herbicide-resistant horseweed biotypes. Four site-years of a field experiment was conducted to determine if fall-planted cereal rye in combination with soybean planted in narrow rows improved management of herbicide-resistant horseweed. The experiment was setup as a split-split-plot design with cover crop termination timing as the main plot, soybean row width as the subplot, and postemergence (POST) herbicide treatment as the sub-subplot. Cereal rye at 67 kg ha^{-1} was drilled the prior fall to each experiment. In the spring, cereal rye was terminated one week prior to and one week after ('Planting Green') planting 'Enlist E3®' soybean and was compared with a no cover control. Within each cover crop treatment soybean was planted in three row-widths: 19-, 38-, and 76-cm. Additionally, glufosinate + 2,4-D choline were applied POST four to six weeks after planting to half of the treatments, while the other half received a non-effective POST application of glyphosate. Depending on site-year, horseweed emerged at two timeframes, late April to early May and mid- to late-June. Biomass was 1,842 and 4,280 kg ha^{-1} for cereal rye terminated one week prior to planting and Planting Green, respectively. Cereal rye reduced horseweed biomass 78% in two of four site-years at the time of early termination. Cereal rye, regardless of termination, reduced horseweed biomass 67% in three of four site-years and density 59 to 63% across all site years at the time of Planting Green termination. At the time of the POST herbicide application, horseweed biomass was reduced 75 to 94% and 59 to 77% when terminated at the Planting Green and early timings, respectively. Narrow soybean row widths also reduced horseweed biomass 56 to 60% in one site-year. Horseweed control was 100% in two of four site-years when an effective POST was applied. At harvest, the main effect of Planting Green reduced horseweed biomass 43 to 48% in two of four site-years, and planting soybean in 19 cm rows reduced horseweed biomass 47%. For the other two site-years, soybean that were planted Planting Green in 19 and 38 cm rows reduced horseweed biomass up to 85 and 57%, respectively. Additionally, horseweed density was reduced across all site-years when soybean was planted into a live cover crop in narrow rows. In conclusion, fall-seeded cereal rye and narrow row widths provided horseweed suppression compared with no cover and 76 cm rows; however, the effects of early termination did not last throughout the season in most cases. Delaying cover crop termination by Planting Green produced higher cover crop biomass and reduced horseweed biomass and density until soybean harvest. These cultural practices have a positive influence on suppressing horseweed that could help with an overall horseweed management strategy; however, the use of an effective POST herbicide is still needed for complete season-long horseweed management.

Field Survey of Herbicide-Resistant Common Waterhemp from Kansas Soybean Fields.
Rui Liu*, Vipan Kumar, Taylor Lambert; Kansas State University, Hays, KS (99)

Common waterhemp (*Amaranthus tuberculatus* L.) is one of the most troublesome summer annual broadleaf weed species in agronomic crops grown in eastern Kansas. Evolution of herbicide resistance has become an increasing concern among field populations of common waterhemp in the region. The main objective of this research was to determine and characterize the resistance pattern among field collected populations of waterhemp to commonly used herbicides in eastern Kansas. A random field survey was conducted in fall of 2018 and seeds of 29 common waterhemp populations were collected from soybean fields. After threshing and cleaning of those seeds, greenhouse experiments were conducted at Kansas State University Agricultural Research Center (KSU-ARCH) near Hays, KS to determine the response of those waterhemp populations to commonly used herbicides. Seedlings from each common waterhemp population were grown in a 50-cell plastic tray (5- by 5-cm sized cell), filled with commercial potting soil. Each plastic tray was maintained with one seedling per cell. Actively growing seedlings (7- to 9 cm tall) from each population were separately treated with POST applied herbicides, including glyphosate (1260 g ha^{-1}), dicamba (560 g ha^{-1}), 2,4-D (870 g ha^{-1}), fomesafen (395 g ha^{-1}), atrazine (1120 g ha^{-1}), chlorsulfuron (26 g ha^{-1}), and glyphosate + 2,4 D choline (1071 + 1008 g ha^{-1}) using automated cabinet spray chamber. Data on dead and alive seedling counts were recorded at 21 days after treatment (DAT), and were used to calculate% of survival. In addition, whole-plant dose-response experiments were conducted on two putative multiple herbicide-resistant (MHR) populations (WH8, WH17) in comparison with susceptible populations (IA, NE) to characterize the levels of glyphosate and chlorsulfuron resistance. Based on 20% survival cutoff, low resistance frequency (> 20% survival) to dicamba and 2, 4-D was observed in one and three common waterhemp populations, respectively. In comparison, higher resistance frequency to glufosinate (21 to 50% survival in 4 populations), fomesafen (30 to 68% survival in 10 populations), atrazine (27 to 98% survival in 23 populations), chlorsulfuron (22 to100% survival in 29 populations), and glyphosate (33 to 100% survival in 29 populations) was observed among tested common waterhemp populations. Based on GR_{50} values, the two putative MHR resistant common waterhemp populations (WH8, WH17) exhibited 48- and 29- fold resistance to chlorsulfuron compared to two susceptible populations. Those two MHR populations also exhibited 10- and 3- fold resistance to glyphosate compared to two susceptible populations. These results suggest that resistance to commonly used herbicides is prevalent among waterhemp populations in eastern KS and Growers should adopt diversified, integrated weed management (IWM) strategies for controlling MHR waterhemp populations.

Impact of Herbicide Use and Cropping Patterns on the Development of Herbicide-Resistant Waterhemp (*Amaranthus tuberculatus*) in Iowa. Ryan Hamberg*, Prashant Jha, Micheal D. Owen, Ramawatar Yadav, Avery J. Bennett, Alexis L. Meadows, Austin Schleich, Edward S. Dearden; Iowa State University, Ames, IA (100)

In the fall of 2019, seed samples of 200 waterhemp populations were collected from georeferenced corn and soybean fields previously used in a random field survey conducted in 2013 in Iowa. The first objective of the research was to determine the temporal (2019 vs. 2013) changes in resistance frequency (% of populations) of herbicide-resistant waterhemp in Iowa corn and soybean. The second objective was to determine how herbicide use and cropping patterns affected those changes. To achieve Objective 1, each population was screened in a greenhouse with eight different herbicide sites of action, five of which were also used in the 2013 survey. Those included inhibitors of ALS (imazethapyr), PS II (atrazine), PPO (lactofen), HPPD (mesotrione), and EPSPS (glyphosate). Response of those populations to glufosinate, 2,4-D, and dicamba was also tested. The first five herbicides were tested at 1X (field-use rate) and 4X rates, while glufosinate, 2,4-D and dicamba were tested at 1/2X and 1X rates. For each population and herbicide dose, 30 plants (10 plants per replication; 3 replications) were sprayed. Experiments were conducted in a randomized complete block design and repeated. Percent visible injury (0 to 100%) was recorded 21 days after application (DAA) and a binomial response (dead/alive) of plant survival was recorded at 28 DAA. A population was determined to be resistant if >50% of the plants survived either dose. To address Objective 2, growers responded to a standard questionnaire to gain insights on their cropping and herbicide use history. Both years exhibited high frequency of resistance to the 4X rate of imazethapyr, which was 95% in 2019 and 85% in 2013. A significantly higher proportion of populations were resistant to glyphosate (4X rate) in 2019 (62%) vs. 2013 (25%). Atrazine resistance (4X rate) increased from 55% in 2013 to 68% of the populations in 2019. For lactofen and mesotrione (4X rates), none of the populations were resistant in 2013 but increased to 3% in 2019. For the populations collected in 2019, 8% and 7% of those survived the field-use rates of glufosinate and 2,4-D, respectively. Only 13% of the populations exhibited three-way resistance in 2013 compared to 58% in 2019. Five-way multiple herbicide-resistant populations increased from none in 2013 to 5% in 2019. A binomial, logit: link function in R, was utilized to assess whether cropping history influenced the resistance development in waterhemp populations over the 6-year period. The analysis indicated a strong relationship ($P < .001$) between HPPD-resistant waterhemp and corn-corn vs. corn-soybean cropping system. Results from this survey indicate that resistance to ALS, PSII and glyphosate is widespread across Iowa. Frequency of resistance to PPO or HPPD herbicides is low but is an increasing concern. Survivors of both 2,4-D and glufosinate produced seeds, currently being evaluated using dose-response assays. These results indicate that Iowa waterhemp populations are quickly evolving resistance to multiple herbicides. Growers will continue to lose the viability of vital herbicide chemistries if proactive IWM strategies (cover crop, reduced row spacing, and harvest weed seed control) are not implemented.

TENDOVO - Setting the Standard for Soybean Herbicides. Brett R. Miller*[1], Peter Eure[2], Tom H. Beckett[3], Scott E. Cully[4], James C. Holloway Jr[5]; [1]Syngenta Crop Protection, Fargo, ND, [2]Syngenta Crop Protections, Greensboro, NC, [3]Syngenta Crop Protection, Greensboro, NC, [4]Syngenta Crop Protection, Marion, IL, [5]Syngenta Crop Protection, Jackson, TN (101)

TENDOVO™ is a new herbicide delivering broad-spectrum residual control of annual grasses and key broadleaf weeds in soybeans from Syngenta Crop Protection. TENDOVO contains *S*-metolachlor, metribuzin and cloransulam-methyl in a ratio that delivers robust rates of all three herbicides in a convenient premixture. In field testing, TENDOVO provides excellent crop safety across soil types and environments in all soybean growing regions of the country. This new herbicide premixture controls annual grasses and most small-seeded broadleaves like waterhemp (*Amaranthus rudis*) and Palmer amaranth (*Amaranthus palmeri*) as well as many key larger-seeded weeds including common and giant ragweed (*Ambrosia artemisiifolia* and *trifida*), morningglories (*Ipomoea* sp.) and velvetleaf (*Abutilon theophrasti*). TENDOVO can be used across all geographies, soil types and tillage systems, and is compatible with common burndown herbicides such as Gramoxone 3.0 SL, glyphosate, 2,4-D and dicamba. TENDOVO helps protect soybean yield by providing early season weed management and will provide an excellent preplant or pre-emergence product as the strong residual base for weed management programs regardless of soybean trait platform.

Efficacy of Pre-Emergence Herbicides on Palmer Amaranth Control as Affected by Cover Crop Termination Timings. Ednaldo A. Borgato*, Sarah Lancaster, Mithila Jugulam, Anita Dille; Kansas State University, Manhattan, KS (102)

Palmer amaranth is a troublesome weed for which integrated management is critical. Nonetheless, pre-emergence (PRE) herbicides are needed to reduce Palmer amaranth interference. A two-year (2020 and 2021) split-plot study was performed near Manhattan, KS, to investigate potential interactions among three cover crop situations: no cover crop (NCC), dead cover crop (terminated 2 weeks prior to soybean planting) and green cover crop (GCC, terminated at planting date) in combinations with six PRE herbicide treatments (flumioxazin, metribuzin, *s*-metolachlor, saflufenacil, sulfentrazone, and non-treated control) applied at labeled rates. Cover crops species grown for this study were triticale + winter peas (100 + 65 kg ha^{-1}) in 2020 and spring oats (100 kg ha^{-1}) in 2021, which were terminated with glyphosate + dicamba (800 + 280 g ha^{-1}) in the dates previously described. Data on cover crop biomass and weed densities were collected at soybean planting to analyze the effect of cover crop biomass as a tool for early-season weed suppression. Additionally, weed control was assessed at 4 weeks after herbicide application (4WAT) to evaluate the effect of residual herbicide activity, cover crop, and herbicide + cover crop for Palmer amaranth control in the soybean crop. Cover crop biomass production was greater as termination was delayed, and having more cover crop biomass resulted in more Palmer amaranth suppression. Among the herbicides used, saflufenacil provided the poorest control in 2020 (38% for NCC and 91% for DCC and GCC) likely due to limited residual activity. Additionally, Palmer amaranth control with metribuzin + DCC and metribuzin + GCC or saflufenacil + DCC and saflufenacil + GCC were greater than metribuzin and saflufenacil without cover crop in 2020. Flumioxazin, metribuzin, *s*-metolachlor and sulfentrazone provided satisfactory control (>84%) regardless of the cover crop treatment. These results suggest no negative effects of combining herbicides with cover crops, indicating that growers can take benefit of combining chemical and cultural methods. The effect of cover crop termination timings versus NCC situations on subsequent soybean establishment and yield needs to be investigated further.

The Powerful Palmer: Confirming Auxin Resistance in Tennessee. Delaney C. Foster*, Larry Steckel; University of Tennessee, Jackson, TN (103)

Reports of Palmer amaranth (*Amaranthus palmeri*) escapes in auxin-based cropping systems became notably more prevalent in Tennessee in 2019 and 2020. It was determined that in many cases, dicamba or 2,4-D were applied timely to small (<10cm) Palmer amaranth. In 2020, greenhouse studies were conducted at Texas Tech University to confirm resistance of Palmer amaranth populations obtained from Tennessee. Results from 2020 showed that Palmer amaranth sourced from Lubbock, TX was 90% controlled at 0.56 kg dicamba ha^{-1}, while 67% of a Palmer amaranth population from Tipton County, TN and <40% of a population from Bedford County, TN were controlled. Similar results were collected from 2,4-D greenhouse screenings. It is important to survey populations from reported herbicide failures and determine the mechanism of resistance. In 2021, field experiments were conducted at the West TN AgResearch and Extension Center and two growers' fields in Madison County, TN and Lauderdale County, TN where reports of Palmer amaranth escapes in previous years were prevalent to determine the level of resistance of these populations to dicamba and 2,4-D. Malathion insecticide (a cytochrome p-450 inhibitor) was investigated to indicate if resistance could be due to enhanced metabolism of the herbicides. Experiments were also conducted to determine the best herbicide programs to control resistant Palmer amaranth populations to make recommendations to Tennessee growers. Preliminary results indicate that in the field, only 40-60% of Palmer amaranth <10 cm tall were controlled using 0.56 kg dicamba ha^{-1} and 45-65% were controlled with 1.12 kg 2,4-D ha^{-1}. Malathion did not increase control with dicamba, regardless of application timing; the tank mix of malathion and 2,4-D increased control compared with 2,4-D alone on <10 cm Palmer amaranth. This result might indicate metabolic resistance is in part a cause for the loss of control. Results on management suggest that the best option for growers will be sequential applications of dicamba or 2,4-D with glufosinate 7-10 days apart with no preference on order of herbicides applied.

Evaluation of a New Multi-Functional Tankmix Partner for Use with Dicamba. Ryan Rector*[1], Kevin Crosby[2], Mickey Brigance[2], Amy Carter[2]; [1]Adjuvants Unlimited, Saint Charles, MO, [2]Adjuvants Unlimited, Memphis, TN (104)

The introduction of dicamba-resistant crops has allowed for use of in-season dicamba to help control herbicide resistant weeds such as Palmer amaranth, waterhemp and horseweed. Several companies have labeled the use of lower volatile dicamba formulations for use in dicamba-resistant crops. The approval of the labeled use was only granted after several years of studies and ecological risk assessments on its use. The testing and evaluation of the approved dicamba formulations resulted in several required tests to be completed in order to have a product added to the approved tankmix website of which spray drift and volatility testing are two of those parameters. This paper will present the results from several tests, including spray drift, volatility, efficacy and pump cycle evaluation, conducted with a multifunctional adjuvant that is approved for use with the lower volatile dicamba formulations.

Multi-state Evaluation of Electrocution as a Rescue Treatment on Escaped Weeds in Soybean. Jacob Vaughn*[1], Mandy Bish[1], Karla L. Gage[2], Prashant Jha[3], Amit J. Jhala[4], William G. Johnson[5], Sarah Lancaster[6], Bryan G. Young[5], Kevin W. Bradley[1]; [1]University of Missouri, Columbia, MO, [2]Southern Illinois University, Carbondale, IL, [3]Iowa State University, Ames, IA, [4]University of Nebraska Lincoln, Lincoln, NE, [5]Purdue University, West Lafayette, IN, [6]Kansas State University, Manhattan, KS (105)

The increasing prevalence of herbicide-resistant weeds in U.S. agriculture has led to increased interest in non-conventional weed control methods, including weed electrocution. The Weed Zapper™ is a commercially-available weed electrocution implement that has become popular among organic and specialty crop producers. In 2021, the Weed Zapper™ was evaluated in conventional soybean systems to determine its effectiveness as a rescue treatment for weeds that escape chemical control. Species evaluated include waterhemp (*Amaranthus tuberculatas*), Palmer amaranth (*Amaranthus palmeri*), common lambsquarters (*Chenopodium album*), velvetleaf (*Abutilon theophrasti*), giant ragweed (*Ambrosia trifida*) and giant foxtail (*Setaria faberi*). The experiment was conducted in Illinois, Indiana, Iowa, Kansas, Nebraska, and two locations in Missouri. Due to regional differences and the time in between treatment at each location, soybean height ranged from 30 to 102 cm, and soybean growth stage ranged from R1 to R6. Weeds were electrocuted at speeds of 4.8 or 8.0 km/h. An additional non-electrocution rescue treatment was evaluated at each location for comparison. The comparison treatments were selected based on the resources available at each location and included interrow cultivation, an interrow mowing device, rope-wick herbicide application, sprayed herbicide applications, and harvest weed seed destruction. Visual control ratings 14 days after application indicated that speed of electrocution had no effect on weed control. However, there was an effect of weed electrocution on the control of different weed species. Electrocution provided highest control of common lambsquarters and waterhemp (mean control of 71% and 65%, respectively), followed by Palmer amaranth (47%), giant foxtail (19%), and velvetleaf (10%). These results indicate that weed electrocution and several other non-chemical techniques have promise for integration into a soybean system, and compared to harvest weed seed destruction, they have the benefit of targeting the weeds prior to seed formation.

Evaluation of the Seed Terminator™ Implement in Missouri Soybean Production Systems.
Travis R. Winans*, Kevin W. Bradley, Mandy Bish, Brian Dintelmann, Haylee E. Schreier, Jake Vaughn, Delbert R. Knerr; University of Missouri, Columbia, MO (106)

The distribution of herbicide resistant weeds such as waterhemp (*Amaranthus tuberculatus*) has resulted in a greater need for a more integrated approach to weed management, especially in U.S. soybean, cotton, and corn production systems. Previous research in Australia has found harvest weed seed destruction (HWSD) to be an effective method of reducing the amount of weed seed returning to the soil. One form of HWSD is the use of impact mills to destroy weed seed exiting the combine during grain harvest. The Seed Terminator™ is one of the most common commercially-available impact mill implements. In 2019 & 2020 we investigated the efficacy of the Seed Terminator™ installed on a Case IH 8250 combine in 5 different Missouri soybean fields that contained significant waterhemp infestations. Results indicate that 22% to 40% of the available waterhemp seed is lost to the soil due to shatter whenever the combine head comes into contact with the waterhemp plant at the time of harvest. Of the remaining seed that is directed into the combine, 51 to 78% is directed into the Seed Terminator™ and 94% of that seed becomes significantly damaged. For 2 of the 5 locations, we were able to evaluate the effects of consecutive seasons of use of the Seed Terminator™ on the same field. Both locations showed a significant reduction of waterhemp in the soil seedbank the spring following harvest. We were also able to determine that engine load was 12.6% higher, fuel consumption was 11.24 liters/hour greater, and harvest proceeded 0.40 kilometers/hour slower whenever the Seed Terminator™ was engaged. Results from this research indicate that the use of impact mills could have a role in reducing soil weed seedbanks in at least the Midwest region of the United States in the future.

Development of a New Multi-Functional Tankmix Partner for Use with Dicamba. Kevin Crosby*[1], Ryan Rector[2], Mickey Brigance[1], Amy Carter[1]; [1]Adjuvants Unlimited, Memphis, TN, [2]Adjuvants Unlimited, St Charles, MO (107)

The introduction of the dicamba weed control system for genetically modified soybeans presents a series of challenges that formulators must overcome to produce a multifunctional adjuvant. Such an “all-in-one” adjuvant used with Dicamba products would have several requirements including: prohibition of ammonium sulfate (AMS) as water conditioner, non acidifying, prevention of driftable fines (< 141 microns) in a dicamba + glyphosate spray mixture, and inclusion of an anti-volatility agent at a sufficient level to prevent dicamba volatility. The prohibition of AMS and pH optimization are related to preventing volatility of dicamba. To meet these restrictions a series of experiments were conducted to examine the effects of individual components on overall adjuvant performance. Baseline components included a volatility control agent, a drift control agent, a water conditioner and surfactant. Data will be presented on development of a multifunctional product demonstrating stability at elevated and cold storage conditions. Optimization of component concentrations resulted in a final formulation with the required performance features.

Using Artificial Intelligence and Computer Vision to Detect Weeds in Soybean Cropping Systems. Isaac Harrison Barnhart*[1], Sarah Lancaster[1], Douglas Goodin[1], Jess Spotanski[2], Anita Dille[1]; [1]Kansas State University, Manhattan, KS, [2]Midwest Research Inc., York, NE (108)

Palmer amaranth (*Amaranthus palmeri* [S.] Wats.) is a major problem weed of soybean (*Glycine max* [L.] Merr.) cropping systems in the midwestern United States. With rising costs of chemical weed control and herbicide-resistant Palmer amaranth cases increasing, new options for control arise when using site-specific weed management strategies. Palmer amaranth detection for targeted post-emergence herbicide applications may be possible using convolutional neural networks for object detection. The objectives of this study were to 1) collect a database of annotated images containing soybeans and Palmer amaranth and 2) test the accuracy of soybean and Palmer amaranth detection using open sourced object detection algorithms. A soybean study at two locations in eastern KS were planted and sprayed with low (60 g), medium (120 g), and high (200 g ai ha^{-1}) rates of Fierce EZ (flumioxazin + pyroxasulfone) to generate varying rates of weed growth within the plots. A total of 4,492 digital images were collected either aerially (via unmanned aerial vehicle, or UAV) or on the ground (via digital camera) between May 27 and July 27, 2021. Soybean plants were photographed between the VC and R2 growth stages, and Palmer amaranth plants were photographed from the first true leaf formation up to maturity defined at the onset of flowering. After annotating both Palmer amaranth and soybean plants with bounding boxes, these images were then used to fine-tune open-source Faster regional convolutional (Faster RCNN) and Single Shot Detector (SSD) models using a Resnet backbone, as well as the You Only Look Once (YOLO) series models. Models were compared to one another using the mean average precision (mAP) with an intersection over union (IoU) threshold set to 0.50. Results demonstrated that YOLO version 5 (YOLOv5) achieved the highest mAP score of 0.75, with precision, recall, and f1 scores of 0.71, 0.70, and 0.71, respectively. The results suggest that open-sourced object detection algorithms such as YOLOv5 can be effectively fine-tuned to detect Palmer amaranth plants in soybean cropping systems. We suggest that such algorithms can be used in equipment such as smart sprayers or herbicide application UAVs to further develop the concept of site-specific weed management of Palmer amaranth.

Antagonism of Group 4 and 15 Herbicides on Volunteer Corn Control with Clethodim.
Marcelo Zimmer*, Bryan G. Young, William G. Johnson; Purdue University, West Lafayette, IN (109)

Volunteer corn (*Zea mays* L.) is one of the most important weeds in soybean production systems in Indiana. High infestations of volunteer corn can occur due to extreme weather conditions, such as wind and hailstorms, defective harvesting equipment, and inadequate setup or operation of combines. Herbicide options for control of volunteer corn in soybean fields vary depending on herbicide-tolerance traits of corn hybrids planted in the previous growing season. Many farmers utilize corn hybrids with stacked resistance to both glyphosate and glufosinate (RR2/LL), limiting herbicide choices for postemergence volunteer corn control. ACCase inhibitor herbicides such as clethodim and quizalofop are often used to control volunteer corn that is tolerant to glyphosate and glufosinate. Previous research indicated that synthetic auxin herbicides such as 2,4-D or dicamba antagonize the efficacy of clethodim, especially in tank-mixtures with glyphosate or acetochlor. The widespread adoption of dicamba- and 2,4-D-tolerant soybeans across many regions of the United States has resulted in increased reports of failed ACCase herbicide applications to control volunteer corn and other grasses. A field experiment was conducted to evaluate control of RR2/LL hybrid corn with clethodim (70 g ai ha^{-1}) in tank-mixtures with dicamba (560 g ae ha^{-1}) or 2,4-D (1065 g ae ha^{-1}) plus Very Long-Chain Fatty Acid (VLCFA) synthesis inhibitor herbicides [acetochlor (1430 g ai ha^{-1}), dimethenamid (950 g ai ha^{-1}), pyroxasulfone (183 g ai ha^{-1}), and *s*-metolachlor (1420 g ai ha^{-1})]. The addition of dicamba to clethodim reduced RR2/LL corn control at 21 days after treatment (DAT) by 20% compared with clethodim alone. Corn density at 21 DAT increased 67% when dicamba was added to clethodim. The addition of acetochlor to dicamba plus clethodim further reduced RR2/LL corn control by 14%. Similarly, the addition of dimethenamid or *s*-metolachlor to dicamba plus clethodim reduced RR2/LL corn control by 8 or 9%, respectively. The addition of 2,4-D to clethodim did not reduce RR2/LL corn control compared with clethodim alone. A windstorm flattened corn plants in the 2,4-D plots a few days after herbicide application, increasing overall RR2/LL corn control in all plots sprayed with 2,4-D. The addition of acetochlor to 2,4-D plus clethodim reduced RR2/LL corn control by 15%. Similarly, the addition of dimethenamid to 2,4-D plus clethodim reduced RR2/LL corn control by 8%. Interestingly, the addition of pyroxasulfone to clethodim tank-mixtures resulted in a 2 to 4% increase in RR2/LL corn control. Data for corn density counts showed similar trends to visual control ratings. These results suggest that the antagonistic effect of VLCFA herbicides in tank-mixtures with clethodim may be exclusive to chloroacetamide herbicides.

Weed Control in Specialty Crops Using Bicyclopyrone. Cristin Weber*[1], Peter Eure[2], Tom H. Beckett[3], Dan Wilkinson[4]; [1]Syngenta Crop Protection, Normal, IL, [2]Syngenta Crop Protections, Greensboro, NC, [3]Syngenta Crop Protection, Greensboro, NC, [4]Syngenta Crop Protection, St. Johns, MI (110)

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

Evaluation of Two Preemergence Herbicides on Weed Control Efficacy for Container Nursery Crop Production. Manjot Kaur Sidhu*[1], Debalina Saha[2]; [1]Michigan State University, Lansing, MI, [2]University of Florida, Apopka, FL (111)

Weed control is an essential aspect in ornamental container nursery production. Weeds not only compete for water, nutrients and space, but also reduce the quality and aesthetic value of nursery plants. In addition, they harbor pests and pathogens that indirectly affect crop growth. All these issues make weed control vital for successful ornamental crop production. Weeds can be controlled using various nonchemical and chemical methods. Nonchemical methods alone are not much effective and can be time consuming. Application of herbicides is an economical and effective method to reduce weed cover. Different preemergence herbicides control weeds at germination stage in container nurseries. Therefore, this experiment was carried out at Horticulture Teaching and Research Center, Michigan State University, to evaluate the granular preemergence herbicides, flumioxazin and flumioxazin + prodiamine at their different rates for their weed control efficacies on common container nursery weed species. Common nursery weed species evaluated included *Amaranthus hybridus* (Smooth pigweed), *Digitaria sanguinalis* (Large crabgrass), *Cardamine hirsuta* (Hairy bittercress), *Ambrosia artemisiifolia* (common ragweed), *Echinochloa crus-galli* (Barnyard grass) and *Abutilon theophrasti* (velvetleaf). The results indicated that flumioxazin + prodiamine at the rate of 200 lbs/acre provided a 100% control of all the weed species evaluated except large crabgrass at 90 days after treatment (DAT). Flumioxazin at the rate of 150 lbs/acre provided a 100% control of smooth pigweed, hairy bittercress, and velvet leaf from 30 DAT till 90 DAT. In addition, Hairy bittercress was best controlled by both flumioxazin and flumioxazin + prodiamine as these herbicides were able to provide complete (100%) control from 30 DAT till 90 DAT.

Tolerance of Four Dry Bean Market Classes (*Phaseolus vulgaris* L. and *Vigna angularis* (Willd.) Ohwi &Amp; H. Ohashi) to Flufenacet, Acetochlor and *S*-Metolachlor Applied Preplant Incorporated. Hannah E. Symington*[1], Allan Kaastra[2], David C. Hooker[3], Darren E. Robinson[3], Peter Sikkema[3]; [1]University of Guelph, Rr#3 Watford, ON, Canada, [2]Bayer Crop Science, Guelph, ON, Canada, [3]University of Guelph, Ridgetown, ON, Canada (112)

Dry bean (*Phaseolus vulgaris* L. and *Vigna angularis* (Willd.) Ohwi & H. Ohashi) is a poor competitor with weeds and is sensitive to many soybean herbicides. Currently, dimethenamid-*P*, EPTC, pendimethalin, S-metolachlor and trifluralin are the only soil-applied herbicides registered for annual grass control, and imazethapyr and halosulfuron are the only two soil-applied herbicides that are registered for broadleaf weed control in dry beans in Ontario, Canada. Acetochlor is a chloroacetanilide herbicide that controls many annual grass and broadleaf weeds. Field trials were conducted near Exeter and Ridgetown, ON, in 2019, 2020 and 2021 to evaluate the tolerance of four market classes of dry beans (azuki, kidney, small red, and white bean) to applications of flufenacet (750 and 1500 g ai ha^{-1}), acetochlor (1700 and 3400 g ai ha^{-1}) and S-metolachlor (1600 and 3200 g ai ha^{-1}) applied preplant incorporated (PPI) representing the 1X and 2X rates. Crop injury, plant height, plant density, shoot biomass, and yield were evaluated. Azuki beans were more sensitive than all other market classes. Crop injury was more pronounced at the 2X rates with all herbicides tested. Flufenacet, acetochlor, and S-metolachlor applied PPI at the 2X rates caused 27, 19, and 25% azuki bean injury, respectively at 1 week after emergence (WAE). Azuki bean plant stand, shoot biomass, height, and seed yield were negatively impacted. Flufenacet, acetochlor, and S-metolachlor applied PPI at the 2X rates caused 6, 7, and 5% injury at 1 WAE to *Phaseolus vulgaris* L. market classes (kidney, small red, and white). There was no effect on stand, height or seed yield of kidney, small red or white bean.

Comparing Newer Versus Older Preemergence Herbicides on Large Crabgrass and Common Ragweed Control in Container Production. Debalina Saha*, Manjot Kaur Sidhu; Michigan State University, East Lansing, MI (113)

Weed control is an important aspect to consider in nursery container production. Growers mostly rely on liquid herbicide applications, on a large scale, but not much on granules. The main objective of this study was to determine the effectiveness of the older herbicide formulations versus the newer herbicides at reducing and eradicating the problematic species that have proliferation in container nursery production. An outdoor container experiment was conducted at the Horticulture Teaching and Research Center (HRTC), Michigan State University, East Lansing in summer 2020. Nursery containers were filled with standard bark-based substrate (85% composted pine bark to 15% peat moss) and amended with controlled-release fertilizer. After filling up the nursery containers, 35 seeds of either common ragweed (*Ambrosia artemisiifolia* L.) or large crabgrass [*Digitaria sanguinalis* (L.) Scop.] was applied to each container. Containers were subjected to full sun condition and were irrigated 1.3 cm daily via overhead sprinkler. Two days after sowing the weed seeds, liquid formulations of herbicides or their combinations were applied with a carbon dioxide backpack sprayer calibrated at an output of 299.3 L ha^{-1}. The newer herbicides and their combinations included 1 × dimethenamid-p + ½ × dithiopyr, 1 × dimethenamid-p + 1 × dithiopyr, 1 × dimethenamid-p + 1 × pendimethalin, ½ × dimethenamid-p + 1 × s-metolachlor, ½ × dimethenamid-p + ½ × s-metolachlor. The older herbicides and their combinations included 1 × napropamide, 1 × napropamide + 1 ×trifluralin, 1 × napropamide + 1 × dithiopyr, and 1 × DCPA. At the time of herbicide application, the temperature was 21°C with a wind speed of 12.8 kmh^{-1} and 54% humidity. Control set without any herbicide treatment was also included. All containers continued to receive daily irrigation of 1.3 cm under full sun condition. There were four replications per treatment for both common ragweed and large crabgrass, consisting of a completely randomized design. Data collection included weed counts at 2, 4, 6, 8, and 10 weeks after treatment (WAT). At 10 WAT, the weed shoot fresh weights were also recorded by cutting the shoots of the emerged weeds at the soil line from each container. Data for each weed species were analyzed separately in SAS 9.4. Results showed that newer herbicides (dimethenamid-p, dithiopyr, pendimethalin, and s-metolachlor) and their combinations have shown 100% control of large crabgrass till week 10, except the combination, 1×dimethenamid-p + ½ × dithiopyr. The older herbicides (napropamide, trifluralin, and DCPA) and their combinations have also provided an acceptable control (60-100%) of large crabgrass till 10 WAT. Whereas newer herbicides and their combinations (except ½ × dimethenamid-p + ½ × s-metolachlor) performed better in controlling common ragweed in comparison to the older herbicides.

Sensitivity of Potato, Tomato and Watermelon to Off-target Movement of Dicamba.
Timothy C. Rice*, Reid Smeda; University of Missouri, Columbia, MO (114)

Buffer distances between dicamba-tolerant (DT) and dicamba-sensitive (DS) crops have been established at 73 m downwind to minimize off-target movement, but these distances are based upon sensitive agronomic crops. In Central Missouri, a field experiment using tomato, potato and watermelon was established to compare plant responses at multiple buffer distances following a dicamba application to adjacent DT soybeans under field conditions. In early May of 2020 and 2021, replicated strips of each transplanted crop (20.1 m row per crop, totaling 61 m per strip) were planted at 8.4, 16.8, 33.6, 50.3, and 67 m west from a 1 ha block of DT soybeans. An adjacent area of land was planted with a similar arrangement, but the vegetables were established east of the DT soybeans. A row of DS soybeans were planted along each row of vegetable crops. DT soybeans were sprayed with dicamba Xtendimax® at 0.56 kg ae ha^{-1} with a prevailing eastern and western wind in 2020 and 2021 respectively. Assessment data included visual injury of tomato, potato, watermelon and DS soybean from 3 to 28 days after treatment (DAT) of DT soybeans. Watermelon vine growth was also assessed over this period. At 28 DAT, tomato and potato yield were determined. Downwind from DT soybeans, DS soybeans exhibited up to 21% visual injury, with damage higher at the 8.4 m distance and decreasing at further distances. Little damage (<2%) was observed upwind from DT soybeans. Tomato and potato visual injury was overall minimal (<8%) both upwind and downwind at all distances, with the exception of tomatoes (~15%) and potatoes (~11%) 14 DAT, 8.4 m downwind of DT soybeans. Vine growth of watermelon was reduced up to 50% for plants at 8.4 m downwind of DT soybeans. Potato yields were reduced up to 50% for all distances in the upwind direction when compared to potatoes downwind of the DT soybeans. The exception were potatoes 8.4 m downwind which were also reduced approximately 50% when compared to the other downwind distances. Tomato yields were similar across all distances and directions. Visual responses of tomato, potato and watermelon to adjacent, dicamba treated DT soybeans were minimal at a 33.6 m buffer distance and beyond, both downwind and upwind. An analysis is currently underway to assess foliar and fruit residue levels of dicamba. Despite the sensitivity of some vegetable crops to dicamba, the upwind buffers established for dicamba tolerant crops appear satisfactory for vegetables also.

Morningglory (*Ipomoea* Spp.) Interference in Triploid Watermelon. Jeanine Arana*, Stephen L. Meyers; Purdue University, West Lafayette, IN (115)

Morningglories (*Ipomoea* spp.) are among the most common and troublesome weeds in the United States. We know very little about morningglory interference with horticulture crops. Morningglories compete for resources and climb and twine around crops, which affects both harvest efficiency and yield. Watermelon is particularly vulnerable to weed competition because of its slow initial growth and wide row spacing. To investigate the interference of morningglories with watermelon, we performed four additive design field trials between 2020 and 2021, two each at Lafayette and Vincennes, IN. With this design, crop density was kept constant, and weed density was varied. Our experiment design was a randomized complete block with four replications. Individual plots were 21 m^2 and contained three rows covered with black plastic mulch. Each row had four hand-transplanted 'Fascination' watermelon plants and two pollinizer plants. Immediately after transplanting watermelon, we established morningglory densities of 0, 3, 6, 12, 18, and 24 per plot with two-week-old seedlings (2020) or seeds (2021) placed into watermelon planting holes. We harvested plots once a week for four weeks in both years except in 2021 at Vincennes. We recorded the weight of each fruit and classified them as marketable (= 4 kg) or non-marketable (<4 kg). One week after the final harvest, we collected aboveground biomass samples from 1 m^2 per plot, separated morningglory and watermelon tissues, and oven-dried them to obtain dry weight. We combined yield loss data from the two 2020 locations and fit it to the rectangular hyperbola model. As morningglory density increased from 3 to 24 per plot, watermelon yield loss increased from 58 to 99%, fruit number decreased 49 to 98%, fruit size decreased 17 to 45%, and aboveground dry weight decreased 82 to 94%. Due to Phytophthora fruit rot, we dropped the 2021 Vincennes location from the analysis. Data from the Lafayette location in 2021 could not be fit to a biologically meaningful regression model. Except for three morningglories per plot, all densities reduced watermelon aboveground dry weight 49-58%, but no morningglory density reduced watermelon yield, fruit size, or fruit number. The predictive model fit to 2020 data makes it possible to calculate economic losses when morningglories escape and interfere the entire season. We recommend repeating the methodology used in 2021.

Evaluating Ways to Reduce Flumioxazin Herbicide Injury to Potato. Harlene M. Hatterman-Valenti*, Collin Auwarter; North Dakota State University, Fargo, ND (116)

Most nightshade species are alternate hosts for insects and diseases that attack potatoes such as Colorado potato beetle and late blight. Eastern black nightshade (*Solanum ptycanthum* Dun.) has been recognized by growers as one of their worst weed problems. This has been attributed to reliance on metribuzin, which provides poor nightshade control, for broadleaf weed management in potato. Flumioxazin provides excellent control of nightshades but has been shown to also cause injury to potato. To alleviate most of the injury to potato, the label restricts use in potato to only 25 states that includes North Dakota. The label further restricts and limits the herbicide application, the application timing, and states: "Many weather-related factors, including high wind, splashing or heavy rains or cool conditions at or near potato emergence, may result in potato injury in fields treated with Chateau EZ Herbicide. On occasion this has resulted in a delay in maturity. Understand and accept these risks before using Chateau EZ Herbicide." Furthermore, the label states: "In areas with historically higher amounts of rainfall during the time of preemergence herbicide applications, including the Red River Valley, Minnesota and North Dakota, the requirement for 2 inches of settled soil is critical to avoid crop injury." The objective was to determine the effect of integrated weed management strategies with flumioxazin on weed control and potato safety under irrigation. Treatments included the labeled use rate and half that rate at three application timings: two days after planting (2 DAP), after regular hilling (9 DAP), hilling immediately after planting and then applying (H9DAP), and then various application timings of flumioxazin and the combination product of metribuzin plus metolachlor. Results discussed at the meeting will include weed control as well and potato yield and grade.

Organic Fiber Hemp Effect on Weed Seedbanks. Andres Fonnegra*; Purdue University, Bogota, Colombia (117)

NO ABSTRACT SUBMITTED

Dicamba Injury on Sunflower, Dry Bean, and Soybean Influenced by Preplant Interval and Rainfall. Nathan H. Haugrud*[1], Joseph T. Ikley[1], Brian Jenks[2], Greg Endres[3]; [1]North Dakota State University, Fargo, ND, [2]North Dakota State University, Minot, ND, [3]North Dakota State University, Carrington, ND (118)

Pre-plant burndown herbicide applications are an essential tool for weed management in no-tillage fields across North Dakota. Glyphosate is the most commonly used active ingredient for pre-plant burndown applications, but tank-mixing an auxin herbicide is becoming more common to control glyphosate-resistant weeds such as kochia. 2,4-D has one of the shortest plant-back intervals among auxin herbicides, but is not useful for producers battling glyphosate+2,4-D resistant kochia. NDSU Extension receives several dozen inquiries every spring regarding the safety of low dicamba rates ahead of planting susceptible broadleaf crops such as sunflower, dry bean, and soybean. Field experiments were conducted in 2021 near Prosper, ND, Minot, ND, and Carrington, ND to evaluate injury from pre-plant dicamba to sunflower, dry bean, and soybean. The Prosper and Minot locations were dryland, while the Carrington location was irrigated. Experiment was an RCBD with a split-split plot arrangement and four replicates. The main plot was planting date with two levels: 7-10 days after dicamba application with no rain and 14+ days after dicamba application with at least 25 mm of rainfall. The subplot was the three broadleaf crops and the sub-sub-plot was the presence or absence of dicamba. Dicamba was applied to half the plots in May 2021 at 140 g ae ha^{-1}. Crop stand, height, and percent visible injury was evaluated 14, 28 and 42 days after crop emergence (DAE). Results indicated pre-plant dicamba at either planting date resulted in unacceptable injury (40-90%) 14 DAE to soybean and dry bean at the two dryland locations. Less injury (42% on soybean and 27% on dry bean) was observed for the first planting date at the irrigated location near Carrington, ND, while minimal injury (<6%) to soybean and dry bean was observed after 14 days and 25 mm of rainfall. Minimal injury to sunflowers (<10%) was observed at all locations when planted after 14 days and 25 mm of rainfall, but 10-23% injury was observed on sunflower planted with no rainfall after dicamba application in the two dryland locations. Significant reductions in soybean and dry bean height were observed at all locations when planted after no rainfall, but only the Prosper, ND location observed height reduction when planted after rainfall. Sunflower height was largely unaffected by any factor. Dicamba labels require at least 120-d plant-back intervals for these crops, but these results indicate the requirement for sunflowers may be lessened under certain conditions.

Efficacy of Preplant Incorporated, Preemergence, and Postemergence Herbicides for Control of Waterhemp (*Amaranthus tuberculatus*) in Dry Bean. Joseph T. Ikley*, Nathan H. Haugrud; North Dakota State University, Fargo, ND (119)

Herbicide-resistant waterhemp (*Amaranthus tuberculatus*) is becoming an increasingly problematic weed to control in dry bean in the Northarvest Bean Growers region, which encompasses North Dakota and Minnesota. Annual survey results indicate that waterhemp is one of the top three worst weeds in 20% of dry bean acres in the Northarvest Bean Growers region. Waterhemp populations resistant to ALS-inhibiting (Group 2) herbicides are of particular concern due to heavy grower reliance on using imazamox and halosulfuron in their herbicide programs. Three trials were conducted in 2021 to evaluate herbicide programs for control of ALS-inhibitor resistant waterhemp. All field experiments were conducted near Fargo, ND, conventionally tilled, and were conducted as RCBD with four replications. The first experiment was comprised of 16 treatments applied either PPI or PRE. Crop injury and waterhemp control ratings were evaluated every two weeks for eight weeks after planting. Waterhemp density and biomass were recorded at eight weeks after planting. PPI-applied herbicides containing EPTC, ethalfluralin, trifluralin, pendimethalin, or sulfentrazone + *S*-metolachlor had the greatest control of waterhemp at the final rating. The second experiment evaluated 12 different POST herbicide programs for control of waterhemp. EPTC + ethalfluralin were applied PPI, and POST treatments were applied to 5-cm waterhemp, with 6 treatments receiving a planned sequential application of the same herbicides products and rates 7 days after initial treatment. Plots were evaluated for crop injury and weed control 7, 14, and 28 days after initial POST treatment. A single application of fomesafen (210 g ha^{-1}) or bentazon + fomesafen (1120 + 210 g ha^{-1}), or sequential applications of bentazon + fomesafen (560 + 105 g ha^{-1} fb 560 + 105 g ha^{-1}), or bentazon + fomesafen + imazamox (560 + 105 + 17.5 g ha^{-1} fb 560 + 105 + 17.5 g ha^{-1}) provided the greatest waterhemp control. The third experiment evaluated a layered residual program approach for season-long waterhemp control. EPTC + ethalfluralin were applied PPI, then 6 different herbicide programs were applied at either the V1 or V3 dry bean growth stage. Waterhemp control was rated every two weeks for eight weeks after the first POST application. Waterhemp density and biomass, as well as dry bean yield were collected at dry bean physiological maturity. All herbicide programs provided at least 85% season-long waterhemp control. Treatments that contained fomesafen (210 g ha^{-1}) applied at V1 dry bean, or any POST program applied at V3 dry bean all provided the greatest waterhemp control. There were no differences in dry bean yield. These trials all provide insight into herbicide programs that can currently be used in conventionally-tilled dry bean to control herbicide-resistant waterhemp. The trials will be repeated in 2022 to provide a second year of data on the utility of these herbicides to control waterhemp.

Morningglory (*Ipomoea* Spp.) Interference in Processing Tomato. Stephen L. Meyers*, Jeanine Arana, Laura Rodriguez, Nathaly Vargas; Purdue University, West Lafayette, IN (120)

Morningglories (*Ipomoea* spp.) are among the most problematic weeds in processing tomatoes, which are planted on bare ground and have few registered herbicides. Two additive field trials were conducted in 2021 at the Meigs Horticulture Research Farm in Lafayette, IN, and the Southwest Purdue Agriculture Center in Vincennes, IN, to quantify the impact of morningglory on processing tomato. '611' tomato plugs were transplanted on May 20 and 27 at Vincennes and Lafayette, respectively, into bare ground in a double row configuration with 38 cm between rows and 46 cm between plants within each row. Plots consisted of a single, double row 6 m long. Morningglory (*I. hederacea* and *I. lacunosa*) seeds were planted after tomato transplanting to achieve densities of 0, 2, 4, 8, 16, and 32 per plot (equivalent to 0.48, 0.96, 1.91, 3.83, and 7.66 m^{-2}). The experiment design was a randomized complete block with four replications. On August 16 (Vincennes) and 25 (Lafayette), five tomato plants in the center of each plot were cut at the soil surface, and their fruit was removed and weighed. In the same portion of the plot, morningglory from one linear meter of the row was harvested. Fresh weight of morningglory and tomato plants were recorded, then the tissues were oven dried to achieve dry weight. Dry weight and tomato yield data were subjected to ANOVA, and mean data were subjected to regression analysis. Percent tomato yield loss, morningglory dry weight m^{-2}, and tomato plant dry weight were fit to 3-parameter exponential models. As morningglory density increased from 0.48 to 7.66 plants m^{2}, predicted morningglory dry weight increased from 118 to 496 g m^{-2}, predicted tomato aboveground dry biomass decreased from 80 to 51 g $plant^{-1}$, and predicted total tomato yield loss increased from 5 to 38%, respectively.

Evapotranspiration of Palmer Amaranth (*Amaranthus palmeri* S. Watson) in Corn, Soybean, and Fallow Under Subsurface Drip and Center-Pivot Irrigation Systems. Jasmine M. Mausbach*[1], Suat Irmak[2], Meetpal S. Kukal[2], Kelsey Karnik[1], Debalin Sarangi[3], Amit J. Jhala[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]Penn State University, University Park, PA, [3]University of Minnesota, St. Paul, MN (121)

Palmer amaranth (*Amaranthus palmeri* S. Watson) is a major biotic constraint in agronomic cropping systems in the United States. Weed-crop competition models offer a beneficial tool for understanding and predicting crop yield losses; however, within these models, weed biological characteristics are unknown, which limits understanding of weed growth in competition with crops under different irrigation methods and how that competition for soil moisture affects crop growth parameters. The objective of this study was to determine the effect of center-pivot irrigation (CPI) and subsurface drip irrigation (SDI) on the actual evapotranspiration (ET_a) of Palmer amaranth grown in corn, soybean, and fallow systems. Twelve Palmer amaranth plants were alternately transplanted one meter apart in the middle two rows of corn, soybean, and fallow subplots under CPI and SDI in 2019 and 2020. Corn, soybean, and fallow subplots without Palmer amaranth were included for comparison. Watermark Granular Matrix soil moisture sensors were installed at 0.3-, 0.6-, 0.9-m depths next to or between three Palmer amaranth and crop plants in each subplot. Soil matric potential data were recorded hourly from the time of Palmer amaranth transplanting to crop harvest. Results suggest irrigation contributes to differences in Palmer amaranth ET_a between cropping systems early in the growing season, where Palmer amaranth had higher ET_a rates under CPI compared to SDI in 2019. Higher Palmer amaranth ET_a rates under SDI compared to CPI in 2020 can be attributed to varying environmental conditions between growing seasons. However, the irrigation effect is likely overcome by differences in crop $ET_{a,}$ later in the growing season. Thus, irrigation and crop management may influence Palmer amaranth ET_a rates. This study provides baseline information about Palmer amaranth evapotranspiration and its relation to Palmer amaranth morphological features (i.e., growth index, biomass, and total leaf area) for future use in mechanistic weed-crop competition models.

Evaluating Potential Fitness Costs Associated with Clopyralid Resistance in Common Ragweed (*Ambrosia artemisiifolia*). Nash D. Hart*, Eric L. Patterson, Erin E. Burns; Michigan State University, East Lansing, MI (122)

Herbicide resistance is an evolved defense mechanism that can have consequences on the fitness of resistant biotypes as a result of diverting resources away from growth and reproduction which may reduce success. Furthermore, resource-based allocation theory implies that the cost of evolved herbicide resistance may present a tradeoff for other stresses within the environment that plant inhabits. Given this, the objective of this study was to evaluate potential fitness costs associated with clopyralid resistance in common ragweed (*Ambrosia artemiisifolia*) in a greenhouse study. The study followed a completely randomized block design with four replications. Factorial combinations consisted of: biotype (clopyralid resistant or susceptible), nitrogen level (low-0 kg N/ha, medium-112 kg N/ha, or high-224 kg N/ha), non-lethal herbicide dose presence or absence (0.105 kg a.i. ha^{-1} or 0 kg a.i. ha^{-1}), and precipitation (ambient-100% field capacity or reduced-50% field capacity). The following measurements were taken every three weeks for the duration of the experiment: photosynthetic output (quantum yield of photosystem II (Phi2), quantum yield of non-photochemical quenching (PhiNPQ), quantum yield of other unregulated losses (PhiNO), and relative chlorophyll (RC)), plant height, and leaf number. Plant maturation rates were assessed by measuring days after emergence to appearance of buds and production of pollen. Finally, plant biomass was weighed after plant senescence and seeds were collected. Data were analyzed using linear mixed-effects models in R and means were separated using Tukey's HSD. The rate of plant maturity was impacted by a three-way interaction between biotype, nitrogen level, and non-lethal herbicide dose (p=0.005). The resistant biotype under high nitrogen and non-lethal herbicide buds emerged 22.3 days earlier than the susceptible biotype under medium nitrogen and non-lethal herbicide dose averaged across precipitation levels. Plant height measured three weeks after emergence was modified by a three-way interaction between biotype, nitrogen level, and non-lethal herbicide dose (p=0.02). The resistant biotype under high nitrogen and no non-lethal herbicide dose was 40% shorter than the susceptible biotype under low nitrogen and non-lethal herbicide dose averaged across precipitation levels. Biomass was altered by a two-way interaction between biotype and herbicide (p=0.017). The susceptible biotype with non-lethal herbicide application had a 22% decrease in plant biomass compared to the susceptible biotype without non-lethal herbicide application, however, there was no difference between resistant and susceptible biotypes regardless of herbicide application, averaged across precipitation and nitrogen levels. Phi2 nine weeks after emergence, was modified by a two-way interaction between biotype and precipitation (p=0.014). The resistant biotype under ambient precipitation had lower levels of Phi2 than the susceptible biotype under ambient and reduced precipitation averaged across nitrogen and herbicide treatments. When RC was measured in the reproductive growth stage there was a three-way interaction between biotype, non-lethal herbicide dose, and precipitation (p=0.0025). The resistant biotype under ambient precipitation and non-lethal herbicide RC was 75% lower compared the susceptible biotype under reduced precipitation and no non-lethal herbicide dose averaged across nitrogen levels. In conclusion, the resistant biotype is potentially less competitive than the susceptible biotype due to shorter height and reduced photosynthetic efficiency during vegetative growth stages.

Effect of Emergence Timing on *Amaranthus tuberculatus* Growth and Seed Production.
Claudia R. Bland*, William G. Johnson, Bryan G. Young; Purdue University, West Lafayette, IN (123)

Waterhemp (*Amaranthus tuberculatus*) has quickly become one of the most common and problematic weed species in Midwest cropping systems. Waterhemp is known to have a wide germination window as well as the ability to produce a large amount of seed. Additionally, waterhemp has the ability to initiate seed production at different plant sizes throughout the growing season as well as rapidly establish a dense population. Field research was conducted to monitor growth characteristics of a population of waterhemp near Francesville, IN (40.911310°N, -86.893604°W), which is known to be resistant to acetolactate synthase (ALS) herbicides, protoporphyrinogen oxidase (PPO) herbicides, atrazine, and glyphosate. For five consecutive weeks starting on May 19th, 40 newly emerged waterhemp plants were flagged. Data on each emergence timing was collected, which included height and branch counts of each plant at 2, 4, and 6 weeks after emergence. The inflorescence date was also recorded and used to calculate growing degree days (GDD) to flowering with a base temperature of 50 degrees Fahrenheit. Plants were harvested when 90% of the seed heads had matured in order to quantify dry weight of all plants in each emergence timing. Data were analyzed in R with Analysis of Variance (ANOVA) and means were separated using Tukey's Honest Significant Difference test. Earlier emergence timings were taller and produced more branches than later emergence timings by six weeks after emergence. Height and number of branches were positively correlated. The last emergence timing we recorded took between 93 and 171 fewer GDD to reach inflorescence than all the other timings. Dry weight data revealed that the first emergence timing accumulated the most mass in comparison to all other timings. The percentage of female plants ranged from 40 to 45 percent in the first two emergence timings and 13 to 30 percent in the last three emergence timings.

Comparative Genomics of Dioecious *Amaranthus* Species. Damilola A. Raiyemo*[1], Lucas Kopecky Bobadilla[2], Patrick Tranel[1]; [1]University of Illinois, Urbana, IL, [2]University of Illinois, Champaign, IL (124)

Waterhemp (*Amaranthus tuberculatus*) and Palmer amaranth (*Amaranthus palmeri*) are agronomically important weeds in the U.S. Their dioecy nature (i.e., male or female reproductive organs on separate individuals) fosters genetic diversity, contributing to the success of the species as problematic weeds. Their dioecious nature, however, potentially also could be exploited using gene-drive technology for novel genetic control strategies. For example, a drive for a maleness gene could result in an all-male population, leading to localized extinction. Towards this goal, approximately 150 candidate gene models within the male-specific Y region (MSY) were previously identified in *A. tuberculatus* and *A. palmeri* with no synteny between the MSY regions of the two species. One or two genes out of these candidate genes are expected to be highly conserved and play a primary role in sex determination in closely related species. To narrow down the candidate gene(s), elucidate genomic sequences that could be manipulated for the management of these weed species via a gene-drive system, and better understand the evolution of dioecy in the *Amaranthus* genus, we sequenced seven additional dioecious species on Illumina Novaseq 6000 to a mean coverage depth between 90X and 130X. Preliminary bioinformatics analyses revealed five genomes, *A. acanthochiton*, *A. arenicola*, *A. floridanus*, *A. australis* and *A. cannabinus*, were more closely related to *A. tuberculatus*, while *A. watsonii* was more closely related to *A. palmeri*. One species, *A. greggii*, exhibited non-proper pairing when mapped to both *A. tuberculatus* and *A. palmeri* genomes, suggesting structural differences between genomes. Further analysis revealed that *A. greggii* had more paralogs relative to other dioecious amaranth species. Additionally, we extracted reads for the five genomes that mapped to the *A. tuberculatus* MSY region and performed variant calling and SNP annotation with GATK and SnpEff, respectively. We identified 73 candidate genes containing SNPs annotated as "HIGH" or disruptive-impact SNPs i.e., genes that likely do not retain their function. Future work will focus on further narrowing down the list of candidate genes with functions in sex determination in dioecious *Amaranthus* species.

Evaluation of Italian Ryegrass Seed Dispersal Prior to and at Wheat Harvest. Amber L. Herman*, Travis Legleiter, Catlin Young; University of Kentucky, Princeton, KY (125)

Harvest weed seed control is a potential option being evaluated in Kentucky to control herbicide resistant Italian ryegrass (*Lolium perenne* spp. *multiflorum*) in soft red winter wheat. One specific method of harvest weed seed control is the use of cage mills to destroy *L. multiflorum* seed found within the fine chaff exiting the combine at harvest. This can only be an efficient and viable option of control if *L. multiflorum* seed is retained on the seed head up to the time of harvest and is able to enter the combines chaff flow. Seed retention and dispersal of *L. multiflorum* were evaluated prior to and at wheat harvest in 2020 and 2021 in Kentucky. Within one week of harvest, both the *L. multiflorum* seed heads and the top layer of soil debris were collected from within a m^2 area for approximately each 0.2 ha of *L. multiflorum* infestation in four Kentucky wheat fields. The *L. multiflorum* seed heads were counted, threshed, and the soil debris samples sieved and cleaned before all the samples were analyzed for the total number of *L. multiflorum* seed. The preharvest samples showed that 11,500 of the seeds m^{-2} remain on the heads prior to wheat harvest whereas 1500 of the seeds m^{-2} shattered and were found in the soil debris samples. Additionally, one site per year was evaluated for *v multiflorum* seed dispersal through a John Deere 9650 combine at harvest. Four 0.4 ha blocks were measured out in the *L. mulitflorum* infested field. Within each 0.4 ha block, 4 combine head shatter loss and 4 chaff samples were collected within a m^2 area. Once each 0.4 ha block was harvested, a grain tank sample was taken before the combine tank was unloaded. All the harvest samples were cleaned and then analyzed for the total number of *L. multiflorum* seeds m^{-2}. The at harvest samples revealed that 4000 seeds m^{-2} passed through the combine and exit with the chaff, whereas 2900 seeds m^{-2} were found in the grain tank, and 2300 seed m^{-2} were lost at the header. There were no significant differences between the chaff, grain tank and header loss proportions of the harvest samples. While most of the *L. multiflorum* seeds will remain on the seed head up to wheat harvest, most of the seeds needs to enter and pass through the combine for a seed destructor to be a viable option of weed control in Kentucky wheat.

Soil Microbial Activity and Degradation of Sulfentrazone, *S*-Metolachlor, and Cloransulam-methyl After Two Years of Cover Crop Use. Lucas Oliveira Ribeiro Maia*, William G. Johnson, Bryan G. Young, Eileen J. Kladivko, Shalamar Armstrong, Joshua R. Widhalm; Purdue University, West Lafayette, IN (126)

The concept of integrated weed management includes the use of cover crops as one alternative method for reducing the selection pressure on herbicides. The addition of soil residual herbicides at cover crop termination can provide additional weed suppression. Limited research has been published on the impact of cover crops on soil microbial activity and how it affects the degradation of soil residual herbicides. Field trials were established at the Throckmorton and Pinney Purdue Agricultural Centers (TPAC and PPAC, respectively) to investigate the influence of cereal rye (*Secale cereale* L.) and crimson clover (*Trifolium incarnatum* L.) cover crops on soil microbial activity and degradation of soil residual herbicides. The experiments followed a corn-soybean rotation, with soybean (*Glycine max* L. Merr) as the cash crop during the 2021 growing season. The experimental design for both trials was a split-plot with cover crops as the main plot and the three herbicide programs as the subplot. The three herbicide programs were: no residual (glyphosate + glufosinate), medium residual (glyphosate + sulfentrazone + *S*-metolachlor), and heavy residual (glyphosate + sulfentrazone + *S*-metolachlor + cloransulam). Herbicide treatments were applied in a single application at cover crop termination two weeks before soybean planting. Cover crop biomass was assessed the day before termination using 0.25 m^2 quadrats. A delayed cover crop planting at PPAC in the fall of 2020 resulted in poor crimson clover survival and was therefore treated as fallow for the data analysis. ß-glucosidase (BG) activity, dehydrogenase (DHA) activity, and herbicide concentrations were determined by collecting soil samples at five days before, 0, 10, 14, 28, 56, and 112 days after termination (DAT) at 0 to 5 cm depth. Herbicide dissipation rate was obtained from the 1st-order kinetics equation: $C_t = C_0e^{-kt}$ and half-life was determined by the equation: $t_{1/2}= \ln2/k$. The use of cover crops provided occasional increases in soil microbial activity relative to the fallow control at PPAC in 2020 and at TPAC in 2020 and 2021. Data from the second year of cover crop use at PPAC showed greater BG and DHA activities in cereal rye plots relative to fallow plots at all sample timings. At PPAC, a 39% average reduction in *S*-metolachlor concentration in the soil was observed in cereal rye plots relative to the fallow treatment after 28 DAT. Similarly, at TPAC, *S*-metolachlor concentrations were 45% lower in the cover crop treatments in comparison to the fallow treatment after 84 DAT. The cover crop treatments resulted in lower concentrations of sulfentrazone in the soil at 14 and 84 DAT at PPAC. No correlation was observed among BG and DHA activities and herbicide concentrations. Although enhanced degradation of *S*-metolachlor and sulfentrazone were observed occasionally, more data is needed to support the hypothesis of this study.

Early Applications of XtendiMax® Herbicide with VaporGrip® Technology in the Roundup Ready® Xtend Crop System. Devin Hammer*; Bayer CropScience, St. Louis, MO (127)

XtendiMax® herbicide with VaporGrip® Technology provides excellent foliar broadleaf weed control of some of the toughest to control species, but it also has the characteristic of soil activity with minimal soil moisture requirement for activation. Previous observations have been made that demonstrate an added initial benefit of spraying XtendiMax with a traditional preemergence (PRE) herbicide application, particularly in extended periods of dry early season weather. Field studies were conducted in 2021 in XtendFlex® soybean to evaluate various PRE weed control options with and without XtendiMax utilizing multiple sites of action. Thirty field studies were conducted in AR, IA, IL, KS, KY, LA, MI, MN, MO, MS, NC, ND, NE, OH, SC, SD, TN, and WI with university academics. Fifteen locations were targeted in conventionally tilled systems and 15 were targeted in no-till systems. Treatments in the no-till trials included glyphosate or other burndown herbicides to effectively evaluate residual weed control. Evaluations were targeted for 14, 21, and 35 days after application. XtendiMax® herbicide with VaporGrip® Technology is a Restricted Use Pesticide.

Confirmation of PPO Resistance in a Wisconsin Giant Ragweed (*Ambrosia trifida*) Accession. Felipe de Andrade Faleco*, Nicholas J. Arneson, David E. Stoltenberg, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (128)

Giant ragweed (*Ambrosia trifida* L.) is one of the most troublesome weed species in Wisconsin corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] cropping systems. Resistance to acetolactate synthase (ALS) and 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) inhibitor herbicides has been previously confirmed in giant ragweed in several U.S. states, including WI. In 2020, a putative fomesafen-resistant giant ragweed accession (AT2) was detected in Rock County, WI. Therefore, our objective was to confirm fomesafen resistance in this accession using dose-response greenhouse experiments. The response of AT2 and a fomesafen-susceptible accession (AT8-EDGE) were evaluated in a RCBD, with four replications per treatment, and two experimental runs. Fomesafen doses were 0×, 0.015×, 0.031×, 0.062×, 0.125×, 0.25×, 0.5×, 1×, 2×, 4×, 8×, and 16× the labeled dose (1×: 263 g ai ha^{-1} + 0.5 v/v % HSOC + 1,428 g ha^{-1} AMS). Herbicides were applied when plants reached 5 to 10 cm in height using a single-nozzle research track spray chamber, equipped with DG9502EVS nozzle, and a carrier volume of 140 L ha^{-1}. At 21 DAT, plant survivorship was assessed visually as dead (no green tissue) or alive (green tissue and evidence of regrowth), and aboveground biomass was harvested. The effective dose of fomesafen that decreased biomass accumulation by 50% relative to non-treated plants (ED_{50}) for AT2 and AT8-EDGE was 210 (± 36) and 7.2 (± 1.1) g ai ha^{-1}, respectively. The ED_{90} for AT2 and AT8-EDGE was 627 (± 271) and 16.6 (± 3.7) g ai ha^{-1}, respectively. The resistance index (ED_{50} RI) was 29.3 (± 6.6), with a p-value < 0.0001. The survivorship at the 1× dose for AT2 and AT8-EDGE were 43% (± 20) and 0% (± 0), respectively. Our results indicate that the AT2 accession is highly resistant to fomesafen. To our knowledge, this is the first confirmed case globally of PPO-inhibitor resistance in giant ragweed. Future research will investigate the mechanism of fomesafen resistance in this accession. Proactive resistance management, including the diversified use of effective herbicides and integrated weed management, will be of paramount importance for long-term sustainable giant ragweed management in WI and beyond.

Using Chaff-Lining to Manage Herbicide-Resistant Waterhemp (*Amaranthus tuberculatus*) in a Soybean-Corn Rotation. Avery J. Bennett*, Prashant Jha, Ramawatar Yadav; Iowa State University, Ames, IA (129)

Waterhemp (*Amaranthus tuberculatus* [Moq.] J.D. Sauer) escapes are becoming very common in soybean production fields of the Midwest United States. This is because of the continuous rise in herbicide-resistant (HR) populations. In a conventional harvesting system, weed seeds are harvested with the crop and spread back into the field along with the crop chaff. However, harvest weed seed control (HWSC) methods such as chaff-lining concentrate weed-seed-bearing crop chaff into a narrow row (chaff-line). These chaff-lines (30 to 50 cm wide) are kept undisturbed during the following growing-seasons, assuming it will create an environment less-favorable for germination and seed survival. Field experiments were conducted in a soybean-corn rotation over two years to quantify the efficacy of chaff-lining to manage waterhemp seed bank at the time of soybean harvest. About 70% of waterhemp seeds were retained on the mother plant at the time of soybean harvest. The chaff-liner (chaff-lining unit attached to the rear of the JD S660 combine) concentrated >99% of waterhemp seeds that entered the combine into the chaff-line. Waterhemp density (4 to 7 plants m^{-2}) in soybean did not influence percent waterhemp seed retention and efficacy of the chaff-liner. Although waterhemp density was 76% higher inside the chaff-line than outside the chaff-line, overall aboveground waterhemp biomass was 63% lower inside the chaff-line than outside the chaff-line. Similarly, waterhemp inside the chaff-line had a delayed (one week) emergence than waterhemp outside the chaff-line. Cumulatively, chaff-lining and preemergence residual herbicides delayed waterhemp emergence by >2 weeks compared with waterhemp emergence outside the chaff-line. In addition, a postemergence herbicide application was needed only inside the chaff-line to manage additional waterhemp emergence, resulting in lower total herbicide use. These results suggest that chaff-lining should be implemented as an integrated weed management (IWM) strategy in soybean-based cropping systems of the Midwest to target waterhemp seeds at the time of harvest and reduce selection pressure exerted by herbicides.

Waterhemp and Palmer Amaranth Survival and Impact on Forage Productivity in Established Alfalfa Fields Across the Northern United States. Mark J. Renz*[1], Erin E. Burns[2], Roger Becker[3], Dwight Lingenfelter[4], John M. Wallace[4]; [1]University of Wisconsin-Madison, Madison, WI, [2]Michigan State University, East Lansing, MI, [3]University of Minnesota, St Paul, MN, [4]Penn State University, University Park, PA (130)

NO ABSTRACT SUBMITTED

Influence of Soil Texture and Moisture on the Competitiveness of Waterhemp (*Amaranthus tuberculatus*) and Palmer Amaranth (*Amaranthus palmeri*). Jeffery K. Stith*, Joseph T. Ikley; North Dakota State University, Fargo, ND (131)

Waterhemp (*Amaranthus tuberculatus*) and Palmer amaranth (*A. palmeri*) are problematic agricultural weeds in North Dakota. Waterhemp has been researched extensively in North Dakota, while Palmer amaranth has been recently introduced to North Dakota. Both species have prolonged emergence patterns, grow rapidly, and have multiple herbicide resistances making them difficult to manage in annual cropping systems. A greenhouse experiment was conducted to compare the growth of waterhemp and Palmer amaranth in two soil types and three water content levels. Waterhemp and Palmer amaranth were planted in competitive arrangements at ratios of 5:0, 4:1, 3:2, 2:3, 1:4, and 0:5. Plants were grown in either a clay soil or sandy loam soil from North Dakota. Pots were kept at water contents of 75%, 50%, or 25% field capacity. Seed were germinated in growth media plugs and transplanted into pots with field soil at the 2-leaf stage to ensure equal starting growth stages in the field soil. Plant heights were measured 5, 6, 7, and 8 weeks after transplant and plant biomass was harvested, dried, and weighed after 8 weeks. Results indicated waterhemp had higher average heights throughout the experiment and a higher average final biomass. No differences in biomass or height were observed from soil type and water content. Waterhemp had significantly reduced height from the competitive effect of Palmer amaranth at the 1:4 waterhemp to Palmer ratio, but no significant differences at the other ratios. The competitive ability of Palmer amaranth with waterhemp and its ability to grow in different environments found in North Dakota will need further research to determine its competitiveness and help guide management recommendations in the future.

Distribution of Herbicide-Resistant Waterhemp (*Amaranthus tuberculatus*) in Minnesota.
Navjot Singh*[1], Thomas J. Peters[2], Seth L. Naeve[1], Ryan P. Miller[3], Debalin Sarangi[1]; [1]University of Minnesota, St. Paul, MN, [2]North Dakota State University, Fargo, ND, [3]University of Minnesota, Rochester, MN (132)

Waterhemp (*Amaranthus tuberculatus*) populations resistant to multiple sites of action have been reported in the midwestern United States. Knowledge about the distribution of herbicide-resistant waterhemp populations could guide the management decisions and help to prevent the spread of resistant individuals. The objective of this study was to investigate the distribution of herbicide-resistant waterhemp populations in row-crop production systems in Minnesota. In the fall of 2020, the seeds of suspected herbicide-resistant waterhemp populations were received from Minnesota growers. Seedlings were grown in the greenhouse at the University of Minnesota, and sprayed with 1× and 3× the labeled dose of atrazine (PS II inhibitor), dicamba and 2,4-D choline (auxin mimics), fomesafen (PPO inhibitor), imazamox (ALS inhibitor), glufosinate (Glutamine synthetase inhibitor), glyphosate (EPSP synthase inhibitor), and mesotrione (HPPD inhibitor). The experiments were repeated twice. Populations with more than 40% survival at 3× the labeled dose of a certain herbicide were categorized as resistant. All 21 populations screened in this study were resistant to imazamox and 66% of the populations were found to be resistant to glyphosate. Three out of 21 populations were resistant to atrazine and fomesafen. One population from Carver County was confirmed to be resistant to mesotrione. Resistance to herbicides from two, three, and four sites of action was confirmed in 66, 14, and 9% of the waterhemp populations, respectively. Three populations showed reduced susceptibility to 2,4-D choline and 15% of the total plants screened survived the 3× the labeled dose of 2,4-D choline. This study confirmed the presence of multiple herbicide-resistant waterhemp populations in Minnesota. As the resistance to HPPD inhibitors and synthetic auxins are on the rise, the growers must be proactive to stop the spread of this biotype and preserve the finite herbicide choices. Keywords: Multiple resistance, postemergence, resistance management, sites of action

Considerations for Postemergence Weed Control Under Drought Conditions. Navjot Singh*, Debalin Sarangi; University of Minnesota, St. Paul, MN (133)

With the rise in global temperature, drought events are becoming severe and persistent. In 2021, many states in the Midwest experienced severe drought, and 42% of Minnesota was under extreme drought in the middle of August. Drought could impact the efficacy of PRE and POST herbicides. The PRE herbicides require moisture for mobilization in the soil and moisture dearth could drastically reduce its activity. Plant leaf tends to droop and roll inwards under drought conditions, reducing plant exposure to POST herbicides and increasing herbicide drop bouncing off. Under drought conditions, some weeds develop thick waxy cuticles as an adaptive mechanism, leading to reduced herbicide absorption. Herbicide droplets tend to dry quickly when drought conditions are accompanied by hot and dry weather, thus reducing herbicide absorption. For systemic herbicides, translocation of herbicides could be diminished due to reduced transpiration. Although the specific response varies with the weed species, environmental conditions, herbicide, and composition; reports of reduced efficacy of Acetolactate Synthase (ALS)- and Acetyl CoA Carboxylase (ACCase)-inhibitor herbicides on grass species are well documented. Despite this, some strategies could help to improve the efficacy of POST herbicides. Application of herbicide doses at the higher end of labeled dose at morning time could reduce the drought impact. The use of appropriate adjuvants and surfactants helps in herbicide retention and absorption by dissolving cuticular waxes. In contrast, some contact herbicides combined with adjuvants showed increased activity in higher temperature, could cause significant crop injury. Therefore, recommendations on herbicide labels should be followed for improving herbicide efficacy and to avoid any crop injury.

Investigating Glufosinate Resistance in a Wisconsin Waterhemp (*Amaranthus tuberculatus*) Accession. Rodrigo Werle, Bruna Loureiro Fontana Bolsoni*, Felipe de Andrade Faleco; University of Wisconsin-Madison, Madison, WI (134)

Waterhemp [*Amaranthus tuberculatus* (Moq.) Sauer] is one of the most problematic weeds of corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] production in the Midwest. When uncontrolled, waterhemp can cause yield losses of more than 70% and 40% in corn and soybean, respectively. Given its dioecious, obligate-outcrossing, and prolific nature, waterhemp is inherently capable of rapidly evolving resistance to herbicides. Further complicating management, waterhemp has a wide emergence window and aggressive growth pattern. To date, waterhemp is confirmed to have evolved resistance to herbicides from six sites of action. The introduction of glufosinate-resistant soybeans (Liberty Link®, LL®GT27, Enlist E3™, and XtendFlex®) provides growers with an additional tool for POST waterhemp management. Glufosinate is a glutamine synthetase-inhibitor herbicide that has been effective for POST waterhemp control. In 2020, a putative glufosinate-resistant waterhemp accession (BRO) was detected in Brooklyn, WI. Therefore, our objective was to confirm glufosinate resistance in this accession using dose-response greenhouse experiments. The response of BRO and two glufosinate-susceptible accessions from WI (A66 and A82) were evaluated in a RCBD, with five replications per treatment and two experimental runs. Experimental units consisted of individual waterhemp plants (656 ml pots filled with Pro-Mix HP Mycorrhizae). Glufosinate doses were 0×, 0.015×, 0.031×, 0.062×, 0.125×, 0.25×, 0.5×, 1×, 2×, 4×, and 8× label dose (1×: 656 g ai ha^{-1} + 1681 g ha^{-1} AMS). Applications were made when plants were 5 to 10 cm-tall using a single-nozzle research track spray chamber, equipped with DG9502EVS nozzle, and a carrier volume of 140 L ha^{-1}. Visual control assessment (0 to 100%) and aboveground biomass were performed at 26 days after treatment (DAT). A log-logistic model was fit to data using the drc package in R software. The effective doses to achieve 50 and 90% control (ED_{50} and ED_{90}, respectively) were estimated. Accessions A66 (ED_{50}=186.5 g ai ha^{-1}) and A82 (ED_{50}=195.3 g ai ha^{-1}) had similar response to glufosinate, whereas the BRO accession had slightly higher tolerance to glufosinate (ED_{50}=263.3 g ai ha^{-1}). Based on the ED_{50} values, the BRO accession had resistance ratios of 1.4- and 1.3-fold when compared to the A66 and A82 accessions, respectively. Biomass data from the experiment are currently being analyzed. Even though resistance was suspected, our results suggest a satisfactory control of BRO using the recommended glufosinate label rate (ED_{90}: 572.1 g ai ha^{-1}). For adequate waterhemp control under field conditions, growers should follow glufosinate label recommendations, such as waterhemp size and application technique to deliver adequate foliar coverage. Environmental conditions that influence glufosinate efficacy, such as light, temperature and humidity, should also be considered before triggering an application.

Opportunities and Challenges for Integrating Cover Crops in Corn-Soybean Rotations in the Upper Midwest. Eric Y. Yu*, Debalin Sarangi; University of Minnesota, St. Paul, MN (135)

Across the United States, farmers are rapidly expanding the adoption of cover crops. Between 2012 and 2017, the countrywide adoption of cover crops increased by 50%. Minnesota has yet to see the same level of increase in the use of cover crops. In 2019, cover crops were planted only on 3.6% of corn and soybeans acres in Minnesota. It can be difficult to implement cover crops in the Upper Midwest due to the small planting window between harvesting of the preceding crops and the first frost, shorter growing season for cover crops, and unpredictable weather including extremely cold temperature and irregular snowfall. Several research concluded that a few cover crop species including cereal rye (*Secale cereale*) perform better than others for states experiencing these difficulties. Cereal rye is a great winter cover crop because it establishes quickly and produces desired biomass and ground cover in a shorter period and can prevent soil compaction. Cover crops can provide several benefits to growers including an increase in soil moisture retention, improve nutrient cycling, and suppress early emerging weeds. This can ultimately lead to higher crop productivity. There are several important things to consider when planting cover crops including seeding and termination timing, seeding rates, and the cover crop species selection. The ability of cover crops to suppress weeds is directly related to the biomass accumulation at the time of termination. This video will discuss the numerous benefits of using cover crops, specifically cereal rye, and things to consider when planting cover crops in the Upper Midwest.

Palmer Amaranth (*Amaranthus palmeri*) Eradication in Minnesota: Timeline, Actions, and Beyond. Eric Y. Yu*[1], Shane Blair[2], Monika Chandler[2], Denise Thiede[2], Anthony Cortilet[2], Jeffrey Gunsolus[1], Roger Becker[1], Debalin Sarangi[1]; [1]University of Minnesota, St. Paul, MN, [2]Minnesota Department of Agriculture, St. Paul, MN (136)

Palmer amaranth (*Amaranthus palmeri* S. Watson) was first reported in Minnesota in 2016 in conservation plantings sown with contaminated seed mixes. Since then, Palmer amaranth has been detected in 11 counties in Minnesota. Also, this weed is now listed on the Minnesota Noxious Weed list as an "eradicate" weed. A rapid genetic test was developed in a partnership with the Minnesota Department of Agriculture (MDA) and the University of Minnesota (UMN) to identify Palmer amaranth in contaminated seed lots. Seed companies adopted genetic testing methods for labeling seeds for sale, thus reducing introductions via seeds. Additionally, the MDA identified that manure spread on crop fields from contaminated screenings fed to livestock resulted in new infestations. The MDA, UMN Extension, Conservation Corps Minnesota and Iowa (CCMI), farmers, and other partners are working together to eradicate these infestations before they become widespread. Management with intensive scouting, torching, prescribed burning, and herbicide application was implemented in 2016 and 2017. By 2018, no Palmer amaranth was found at any of those initial infestation sites. Similar success to newer infestations was achieved using the same methods. The MDA recorded management activities and documented a comprehensive timeline of Palmer amaranth infestations in Minnesota. Currently, the MDA and UMN Extension are using drone-based imagery techniques to identify and locate Palmer amaranth in crop and non-croplands in Minnesota.

Enlist Weed Control System in Enlist E3 Soybean. David M. Simpson*, Joe Armstrong; Corteva Agriscience, Indianapolis, IN (137)

Enlist E3® soybean (*Glycine max*), commercially launched in the US in 2019, provides growers the flexibility to utilize 2,4-D choline, glyphosate and/or glufosinate for postemergence weed control. Enlist One® herbicide contains 2,4-D choline. Enlist Duo® herbicides contains 2,4-D chloline + glyphosate. Colex-D® technology, in both Enlist One and Enlist Duo herbicides, reduces the potential for off-target movement by reducing volatility and driftable fines compare to traditional 2,4-D products. With over 50 million Enlist E3 soybean acres treated since 2019, the reduced potential for off-target movement of Enlist herbicides has been validated time after time. The Enlist® weed control system utilizes multiple modes of action in preemergence and postemergence herbicide applications. Postemergence applications of Enlist One plus glufosinate or glyphosate following a pre-emergence residual herbicide provides control of glyphosate resistant waterhemp (*Amaranthus tuberculatus*) Palmer amaranth (*Amaranthus palmeri*), giant ragweed (*Ambrosia trifida*) and horseweed (*Erigeron canadensis*) in additional to other annual broadleaf and grasses.

What is the Better Tankmix Partner, Saflufenacil or Metribuzin, with Dicamba, 2,4-D Ester, Halauxifen-methyl or Pyraflufen-ethyl/2,4-D, Applied Preplant, for Glyphosate-Resistant Horseweed Control in Soybean? Meghan E. Dilliott*, David C. Hooker, Darren E. Robinson, Peter Sikkema; University of Guelph, Ridgetown, ON, Canada (138)

Horseweed (*Erigeron canadensis* L.) is a facultative winter annual native to North America. Repeated applications of glyphosate have resulted in the rapid evolution of glyphosate-resistant (GR) horseweed. GR horseweed interference can reduce soybean yield up to 93%. Glyphosate plus dicamba, 2,4-D ester, halauxifen-methyl or pyraflufen-ethyl/2,4-D applied preplant (PP) provide variable GR horseweed control in soybean. The objective of this study was to determine if the addition of saflufenacil or metribuzin to glyphosate plus dicamba, 2,4-D ester, halauxifen-methyl or pyraflufen-ethyl/2,4-D will improve the level and consistency of GR horseweed control. Four field trials were conducted over a two-year period (2020, 2021) in commercial fields with GR horseweed populations. Glyphosate plus dicamba, 2,4-D ester, halauxifen-methyl or pyraflufen-ethyl/2,4-D controlled GR horseweed 96, 77, 71, and 52%, respectively at 8 weeks after application (WAA). The addition of saflufenacil or metribuzin to glyphosate plus dicamba or 2,4-D ester did not improve GR horseweed control 8 WAA. The addition of saflufenacil or metribuzin to glyphosate plus halauxifen-methyl improved GR horseweed control 27 and 25%, respectively 8 WAA. The addition of saflufenacil or metribuzin to glyphosate plus pyraflufen-ethyl/2,4-D improved control 47 and 37%, respectively 8 WAA. The consistency of GR horseweed control was improved from the addition of saflufenacil or metribuzin to glyphosate plus dicamba, 2,4-D ester, halauxifen-methyl or pyraflufen-ethyl/2,4-D compared to the herbicides applied alone. Synergism was observed when metribuzin was added to glyphosate plus halauxifen-methyl and when saflufenacil or metribuzin were added to glyphosate plus pyraflufen-ethyl/2,4-D 8 WAA; interactions between the other tankmix partners were mostly additive.

STOP THE SPREAD: Revisiting the Status of Herbicide-Resistant Waterhemp in Iowa Corn and Soybean Fields. Ryan Hamberg*; Iowa State University, Ames, IA (139)

For decades, farmers have utilized herbicides as their main method of weed control. This overreliance has led to the evolution of herbicide-resistant weeds across the U.S. One such weed, and the topic of this video, is waterhemp. Waterhemp possesses unique biological characteristics that give it a high propensity to develop resistance to control tactics. Some of these characteristics include an extended emergence period, prolific seed production, dioecious reproductive habit, and high genetic diversity. This has led to waterhemp evolving resistance to six herbicide groups commonly utilized by corn and soybean growers in the Midwest. With the unlikelihood of any new herbicide site of action commercialized soon, it is crucial to preserve the utility of existing herbicide chemistries. The first step in mitigating the spread of herbicide-resistant waterhemp is early detection. To fulfill this goal, in 2019, we revisited over 200 randomly selected corn and soybean fields across Iowa that were part of a previous survey conducted in 2013. We collected seed samples of waterhemp from each georeferenced field (used in the 2013 survey) and screened those populations with seven different herbicide sites of action, commonly utilized in corn and soybean. Those included ALS (imazethapyr), PS II (atrazine), PPO (lactofen), HPPD (mesotrione), EPSPS (glyphosate), GS (glufosinate), and synthetic auxins (2,4-D, and dicamba). The goal of this research was to understand the status of herbicide-resistant waterhemp in Iowa and compare the change in frequency (% of populations) of evolved herbicide resistance over the last six years (2019 vs. 2013). When comparing results between 2019 vs. 2013 surveys, there was a significant increase in the frequency of resistance to most herbicides tested. Frequency of resistance to the ALS inhibitor at the 4X field use rate was 95% in 2019 compared to 85% in 2013. Glyphosate resistance (4X rate) increased significantly from 25% in 2013 to 62% in 2019. Resistance frequency to atrazine (4X rate) increased from 55% in 2013 to 68% in 2019. None of the populations from the 2013 survey were resistant to lactofen or mesotrione (4X rates) in 2013; however, in 2019, 3% were resistant to 4X rates of the herbicides. For the populations collected in 2019 from the same fields (2013 survey), 8% and 7% of those survived the field use rates of glufosinate and 2,4-D, respectively. Furthermore, the survivors produced seeds, which are currently being used for conducting dose-response assays. There was a significant increase in the proportion of populations with three-way resistance (ALS, PS II & EPSPS), from 13% in 2013 to 58% in 2019. Furthermore, none of the 2013 populations were 5-way (ALS, PS II, EPSPS, PPO & HPPD) multiple-resistant, compared with 5% of the same populations collected in 2019. These results indicate that Iowa waterhemp populations are quickly evolving resistance to herbicides over time, implying that growers will continue to lose the viability of vital herbicide chemistries if proactive strategies are not implemented. Multi-tactic integrated weed management (IWM) strategies are urgently needed to slow down the further spread of multiple herbicide-resistant waterhemp in Iowa.

The Tolerance of Cucurbit Crops to Reflex Herbicide. Jeanine Arana*, Stephen L. Meyers; Purdue University, West Lafayette, IN (140)

Reflex (a.i. fomesafen) is registered for preemergence use in cucurbits in some Midwestern states but not in Indiana. A special local needs label can be requested to make this herbicide available for Indiana farmers through section 24 - subsection 'c' of the Fungicide, Insecticide, and Rodenticide Act (FIFRA). Crop safety data must be documented in-state and submitted for approval. We developed a research program to determine the tolerance of pumpkin, winter squash, summer squash, and watermelon to fomesafen. Between 2020 and 2021, we performed four trials for each crop at Lafayette, Vincennes, and Wanatah, IN. Experimental units consisted of three 4.9 m long bare ground raised-bed rows for pumpkin and winter squash trials and three raised-bed rows covered with black polyethylene mulch for the watermelon trials. In each row, we hand-seeded four pumpkins or winter squash or hand-transplanted four watermelon seedlings. Experimental units for the summer squash consisted of a single raised-bed 4.9 m long covered with black polyethylene mulch into which we hand-transplanted eight seedlings. The experiment had a factorial treatment arrangement of two varieties for each crop (pumpkin: 'Bayhorse Gold' and 'Carbonado Gold'; winter squash: 'Autumn Delight' and 'Betternut 900'; watermelon: 'Fascination' and 'Exclamation'; and summer squash: 'Blonde Beauty' and 'Spineless Beauty' or 'Liberty') by five fomesafen rates (0, 280, 560, 840 and 1220 g ai ha^{-1}), except for watermelon (0, 210, 420, 630 and 840 g ha^{-1}). The experiment design was a randomized complete block with four replications. The herbicide rate and the crop varieties were the explanatory variables. The response variables were percent of emergence reduction (pumpkin and winter squash only), visible crop injury on a scale of 0 (no injury) to 100% (crop death), and yield loss (fruit number reduction and total marketable fruit weight reduction). Data were subjected to ANOVA and then to non-linear regression. The data suggested that fomesafen can be broadcast applied at 280 g ha^{-1} on the bare ground immediately after seeding pumpkin or winter squash, but there is a risk of increased crop injury with increasing rainfall. Fomesafen can be safely applied over-the-top of plastic at 280 g ha^{-1} one day before transplanting summer squash and at 210 g ha^{-1} seven to nine days before transplanting watermelon.

Weed Electrocution: a Viable Option in Soybean Production? Haylee E. Schreier*, Jacob E. Vaughn, Travis Winans, Delbert Knerr, Mandy Bish, Kevin W. Bradley; University of Missouri, Columbia, MO (141)

Because of the continuing issue of herbicide-resistant weeds, alternative methods of weed control are being researched. Weed electrocution is one alternative method that was researched in the summers of 2020 and 2021. A commercially available implement called the Weed Zapper™ was used to test the effectiveness of electrocution on several weeds common to Midwest soybean production. One experiment focused on waterhemp [(*Amaranthus tuberculatas* (Moq.)] control within soybeans [(*Glycine max* (L.)], with electrocution as a rescue treatment. Along with waterhemp control, potential soybean injury and yield loss were observed. To do this, the electrocution boom maintained nearly constant contact with upper 8 cm of the soybean canopy. Electrocution timings took place at the R1, R2, R3, R4, R5, and R6 soybean growth stages and at a constant implement speed of 4.82 km/h. Overall, greater waterhemp control was achieved at later soybean growth stages, as this is when waterhemp plants escaped above the canopy. In 2020, up to 18% soybean visual injury occurred following electrocution at the R3 timing, which is correlated with a 23% yield loss. However, this likely represents a worst-case scenario as constant contact of the boom with the soybean canopy would not have to occur when a clear height difference exists among the soybean and waterhemp. Overall, research results show the potential of weed electrocution as a late season rescue treatment in soybean.

Effect of Water Conditioners on Glyphosate, Glufosinate and 2,4-D Efficacy. Barbara Vukoja*[1], Vinicius Velho[1], Greg R. Kruger[2], Christopher Proctor[3]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]BASF, Durham, NC, [3]University of Nebarska Lincoln, Lincoln, NE (142)

Water is the most frequently used carrier in herbicide applications. Water properties, such as hard water cations and pH, can have an impact on herbicide performance. Hard water cations and high pH levels can reduce herbicide efficacy. The use of water conditioners (WCs) is commonly recommended to overcome loss in efficacy from high levels of water cations or high pH levels. Most research has been done on evaluating the addition of ammonium sulfate (AMS) to weak acid herbicides. Hence, the objective of this study was to evaluate the efficacy of citric acid, phosphoric acid, and AMS used in a tank-mixture with glufosinate, glyphosate or 2,4-D across a range of droplet sizes. A greenhouse study was conducted where herbicides were sprayed alone and in a tank-mixture with WCs on waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer), common lambsquarters (*Chenopodium album* L.) and green foxtail (*Setaria viridis* L. Beauv.), except for 2,4-D on green foxtail. The water chemical properties were adjusted to 240 ppm (expressed as $CaCO_3$) and 7 pH prior to adding herbicides and WCs. Non-venturi nozzles in combination with PWM (pulse width modulation) technology were used to deliver the treatments with 150, 450, 600 and 900 µm VMDs (volume median diameter). Treatments were applied using three-nozzle spray chamber at 140 L ha^{-1}. Application speed was adjusted for each nozzle type by pressure combination to deliver targeted VMD. At 21 days after treatment (DAT) above ground weed biomass was harvested and dried to constant mass. Dry weight was converted to percentage of dry biomass reduction compared to nontreated control. The results have shown that addition of phosphoric acid across herbicides provided best control for common lambsquarters compared to herbicides alone and in a tank-mixture with other WCs. Droplet size only affected efficacy for 2,4-D + citric acid, where smaller VMDs (150 and 450 µm) were more efficacious than larger VMDs (600 and 900 µm) on common lambsquarters. Addition of any WC to 2,4-D was beneficial for waterhemp biomass reduction, whereas addition of WCs to glufosinate did not increase waterhemp biomass reduction. Highest waterhemp control was observed when glyphosate was sprayed alone at 600 and 900 µm, with biomass reduction of 80 and 74%, respectively, which was not different than glyphosate + phosphoric acid (450, 600 and 900 µm), glyphosate + AMS (600 µm) and glyphosate + citric acid (450 and 900 µm). The addition of any WC to glufosinate did not improve efficacy over glufosinate alone across droplet sizes on green foxtail control. There were no differences in glyphosate control between treatments.

Confirmation and Control of Imazamox-Resistant Shattercane. Vipan Kumar*, Rui Liu, Taylor Lambert, Ramsamy Perumal; Kansas State University, Hays, KS (143)

Shattercane (*Sorghum bicolor* L.) is a summer annual grass weed species commonly found in grain sorghum producing regions, including Kansas. Recent development and commercialization of grain sorghum hybrids with tolerance to acetolactate synthase (ALS) and acetyl-CoA-carboxylase (ACCase) inhibiting herbicides will allow producers to use these herbicides for in-season control of grass weed species. In a recent field survey, three shattercane populations (DC8, GH4, and PL8) collected from sorghum fields from western Kansas survived the field-use rate (52 g ha^{-1}) of POST applied imazamox. The main objectives of this research were to (1) confirm and characterize the level of resistance to imazamox in those putative imazamox-resistant (IMI-R) shattercane populations, (2) understand the underlying mechanism of resistance to imazamox, and (3) determine the effectiveness of alternative POST herbicides for controlling IMI-R shattercane populations. Whole plant dose-response experiments were conducted in a greenhouse conditions at Kansas State University Agricultural Research Center near Hays, KS. Imazamox susceptible shattercane population collected from sorghum field in Rooks County, KS was also included for comparison. Plants from each selected shattercane population (DC8, GH4, PL8, and SUS) were grown in 10- by 10-cm sized squared plastic pots containing commercial potting mixture. Experiments were conducted in a randomized complete block (blocked by population) design with 12 replications. At 3 to 4-leaf stage, plants from each population were sprayed using a cabinet spray chamber with various doses of imazamox: 0, 13, 26, 52, 78, 104, 156, and 208 g ha^{-1}. Each dose of imazamox included methylated seed oil (MSO) at 1% v/v. Data on percent visual injury and shoot dry weights were collected at 21 days after treatment (DAT) and were analyzed using 3-parameter log-logistic model in *drc* package in *R* software. Based on GR_{50} values, all three populations exhibited a 3.5- to 5.3-fold resistance to imazamox as compared to SUS population. Sequencing of ALS gene did not reveal any known point mutation among all 3 IMI-R populations. However, a pretreatment of malathion at 1000 g ha^{-1} followed by a POST application of imazamox at field-use rate (52 g ha^{-1}) completely controlled all three IMI-R shattercane populations, suggesting a metabolism-based mechanism for imazamox resistance. In a separate greenhouse study, POST treatments of nicosulfuron, quizalofop, clethodim and glyphosate provided excellent control (98 to 100%) of all 3 IMI-R populations at 21 DAT. These results confirm the first case of metabolism-based resistance to imazamox in shattercane populations from Kansas.

Interactions of 4-hydroxyphenylpyruvate Dioxygenase (HPPD)-inhibiting and Reactive Oxygen Species (ROS)-Generating Herbicides for the Control of Annual Weed Species in Corn. John C. Fluttert*[1], Mariano Galla[2], David C. Hooker[1], Darren E. Robinson[1], Peter Sikkema[1]; [1]University of Guelph, Ridgetown, ON, Canada, [2]ISK Biosciences, Concord, OH (144)

The interaction between 4-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibiting herbicides and photosystem II (PSII)-inhibiting herbicides has been documented. Herbicides that inhibit HPPD reduce the ability of a plant to quench reactive oxygen species (ROS) while PSII-inhibitors upregulate the production of ROS which can ultimately cause cell death by lipid peroxidation. The interrelated modes of action of HPPD- and PSII-inhibitors has been credited for the synergistic interaction between the two herbicides for the control of several weed species; however, additive interactions between the herbicides are also common. Recent research has identified that ROS generation and subsequent lipid peroxidation is the cause of cell death by the glutamine synthetase-inhibitor, glufosinate. Therefore, a basis for synergy exists between glufosinate and HPPD-inhibitors; however, the interaction has not been intensively studied. Four field trials were conducted in southwestern Ontario, Canada in 2020 and 2021 to determine the interaction between HPPD-inhibiting (mesotrione and tolpyralate) and ROS-generating (atrazine, bromoxynil, bentazon, and glufosinate) herbicides for the control of several annual weed species in corn (*Zea mays* L.). Tank-mixes of HPPD-inhibitors + ROS-generators were synergistic for the control of common ragweed (*Ambrosia artemisiifolia* L.) except for tolpyralate + glufosinate which was antagonistic 8 weeks after application (WAA). Tolpyralate + glufosinate was also antagonistic for the control of *Setaria* spp. at 8 WAA. All herbicide tank-mixes were additive for the control of wild mustard (*Sinapis arvensis* L.) at 8 WAA except for the synergistic tank-mixes of tolpyralate plus atrazine or bromoxynil. Results from this research demonstrated that ROS-generators plus mesotrione or tolpyralate controlled common ragweed and wild mustard >90% at 8 WAA except for common ragweed control with tolpyralate + glufosinate. Glufosinate was the best tank-mix partner with mesotrione for the control of *Setaria* spp. at 8 WAA. Tolpyralate tank-mixed with any ROS-generator controlled *Setaria* spp. equivalently at 8 WAA.

Integrated Management of Multiple Herbicide-resistant Palmer Amaranth in Corn.
Ramandeep Kaur*; University of Nebraska-Lincoln, Lincoln, NE (145)

A survey by Weed Science Society of America has listed Palmer amaranth as # 1 troublesome weed in agronomic crops in the United States. Six broadleaf weeds in Nebraska have been confirmed resistant to glyphosate including waterhemp, common ragweed, giant ragweed, marestail, kochia, and most recently Palmer amaranth. A survey reported that about 6 million acres in Nebraska are infested with at least one glyphosate-resistant weed. Confirmation and widespread occurrence of atrazine, glyphosate, and ALS-inhibitor-resistant Palmer amaranth in Nebraska is a concern for corn producers. Nebraska is one of the largest corn producing states in the United States with the production of corn on about 9 to 10 million acres annually. Optimum corn yield depends on number of factors including effective weed management. Agronomic and weed management strategies have been applied to alleviate the evolution and spread of multiple herbicide resistant weeds. Thus, with this prospective, the following field experiments were conducted to develop integrated approach for management of atrazine, glyphosate, and ALS inhibitor- resistant Palmer amaranth in herbicide-resistant and food grade white field Corn.Research experiments: 1. Effect of row spacing and herbicide programs for control of atrazine, glyphosate, and ALS-inhibitors-resistant Palmer amaranth in Roundup Ready/Liberty Link corn 2. Herbicide programs for control of resistant Palmer amaranth in Enlist corn 3. Post-emergence (rescue) herbicide programs for control of resistant Palmer amaranth in Roundup Ready/Liberty Link corn at two growth stages 4. Comparison of residual activity of pre-emergence herbicides for control of resistant Palmer amaranth in food grade white corn.

Assessing Factors Influencing Dicmaba Volatility in a Controlled Environment. Matthew Osterholt*, Julie M. Young, William G. Johnson, Joshua R. Widhalm, Bryan G. Young; Purdue University, West Lafayette, IN (146)

The commercialization of dicamba-resistant soybean (*Glycine max* (L.) Merr.) has increased the potential for off-target dicamba movement to sensitive crop species. While application restrictions continue to expand on how dicamba may be applied, a broader understanding of the factors that influence off-target movement, especially volatility, is well desired. Recent research has indicated that the addition of ferrous sulfate at 0.02M within the spray solution increases dicamba volatilization. While having spray solutions that reach this level of iron is possible with the addition of certain foliar fertilizers, these levels are unrealistically high for iron levels occurring in ground water. Therefore, further investigation is warranted into whether concentrations of iron commonly found in Indiana groundwater influences dicamba volatility. As a result, a controlled environment experiment was conducted to quantify the impact of varying concentrations of ferrous sulfate on dicamba volatilization. The concentrations of ferrous sulfate added to the dicamba spray solutions were none, 0.0001M, 0.001M, 0.01M, and 0.02M. The 0.0001M concentration of ferrous sulfate coincides with the amount of iron commonly found in Indiana groundwater. The diglycolamine (DGA), diglycolamine with VaporGrip® (DGA+VG), or N,N-Bis-(3-aminpropyl)methylamine (BAPMA) salts of dicamba were applied to glass slides at a rate of 560 g ae ha^{-1} and placed into a closed chamber for 48 h while air samplers captured any volatilized dicamba. The air samplers were than processed and quantified for dicamba using LC-MS. There were no differences in dicamba volatility when concentrations of 0.0001M and 0.001M ferrous sulfate were added to the spray solution compared to each respective dicamba formulation applied alone. For the DGA+VG formulation, dicamba volatility increased with the addition of 0.01M ferrous sulfate and was the highest when applied with 0.02M ferrous sulfate. For the DGA and BAPMA formulations, dicamba volatilization was the highest when applied with 0.01M ferrous sulfate. However, dicamba volatilization decreased when applied with 0.02M ferrous sulfate to levels similar to dicamba applied with the 0.0001M ferrous sulfate concentrations. This decrease in volatility observed from the BAPMA and DGA formulations when applied in conjunction with 0.02M ferrous sulfate compared to the 0.01M ferrous sulfate treatments may be from ferrous cations forming complexes with the dicamba anions and reducing volatilization. Overall, these results indicate that when concentrations of iron sulfate are present in the spray solution that coincide with iron levels found in Indiana ground water, there is no increase in dicamba volatilization.

Control of Glyphosate/Glufosinate/Dicamba-resistant Soybean Volunteers in Corn with Postemergence Herbicides. Mandeep Singh*, Amit J. Jhala; University of Nebraska-Lincoln, Lincoln, NE (147)

Crop volunteers have emerged as weeds during the following year with widespread adoption of herbicide-resistant crops. Soybean volunteers are not a serious concern but might become an issue due to unexpected weather events that results in high level of harvest losses, and availability of soybean with multiple herbicide-resistance traits. Certain situations such excessive rainfall can limit application of PRE herbicides leaving only POST herbicides as an option to control soybean volunteers. The objectives of this study were to evaluate efficacy of labeled POST corn herbicides for control of dicamba/glufosinate/glyphosate-resistant (XtendFlex) soybean volunteers in Enlist™ corn and their effect on crop injury and yield. A field experiment was conducted in 2021 at South Central Ag Lab, University of Nebraska, Clay Center, NE. Dicamba/glufosinate/glyphosate-resistant soybean seeds harvested from previous season were cross-planted at 125,000 seeds ha^{-1} to mimic soybean volunteers. After 2 days, Enlist™ corn was planted at 87,500 seeds ha^{-1}. Acetochlor/clopyralid/mesotrione, atrazine/bicyclopyrone/mesotrione/S-metolachlor, and clopyralid/flumetsulam provided 99 % control of soybean volunteers at 28 d after POST herbicides applied through pre-harvest. Acetochlor/mesotrione, dicamba/tembotrione, and dimethenamid-*P*/topronezone provided 78%-85% and 95%-98% control of soybean volunteers at 28 and 56 d after POST, respectively. Corn yield was not affected across all treatments. It is concluded that POST herbicides are available to control dicamba/glufosinate/glyphosate-resistant soybean volunteers in Enlist™ corn.

***Amaranthus* Spp. Has Redefined Weed Management in Sugarbeet in Minnesota and North Dakota.** Alexa L. Lystad*, Thomas J. Peters; North Dakota State University, Fargo, ND (148)

Sugarbeet (*Beta vulgaris* L.) producers in Minnesota and North Dakota reported waterhemp [*Amaranthus tuberculatus* (Moq.) J.D. Sauer] as their most troublesome weed control challenge on 500,440 acres or 78% of sugarbeet production acres in 2021. Sugarbeet growers apply layered soil residual herbicides at planting, at the 2 to 4 lf stage and at the 6 to 8 leaf stage for waterhemp control. Use of layered soil residual herbicides is a substantial transformation in behavior from 2000 and 2010 when only 13% and 3% of sugarbeet fields, respectively, were treated with soil residual herbicides. Soil residual herbicides are applied preemergence and postemergence to sugarbeet and preemergence to waterhemp for control. Timely rainfall is an important and often overlooked component in waterhemp control since soil residual herbicides must be incorporated into the soil for effective waterhemp control. However, fields received only 21-, 73-, and 28-mm rainfall in May, June, and July, 2021, respectively, as compared to 30-yr averages of 73-, 95- and 77-mm rainfall in a random sample. Producers asked: a) should one apply soil residual herbicides when the durations of days between rainfall to incorporate herbicides was greater than previous years; and b) which application (PRE, EPOST or POST) in a layered waterhemp control plan was the most important component in a season with below normal rainfall. Waterhemp control and sugarbeet tolerance was investigated at Fargo, ND, Moorhead, MN, and Blomkest, MN in 2021. Each experiment was a RCBD design and a factorial treatment arrangement, one factor being soil residual herbicide treatment at planting and the other factor being soil residual herbicide treatment POST to sugarbeet (PRE to waterhemp control). Waterhemp control from repeat applications of glyphosate and ethofumesate at 1.10 + 0.14 kg ha^{-1} ranged from 31% to 79% waterhemp, 55 to 80 days after planning across four experiments despite dry conditions that seem to reduce waterhemp emergence. Ethofumesate or ethofumesate plus *S*-metolachlor PRE or one or more chloroacetamide herbicide applications with glyphosate and ethofumesate improved waterhemp control as compared to repeat glyphosate plus ethofumesate mixtures alone. Soil residual herbicides applied postmergence to sugarbeet and preemergence to waterhemp offer the greatest improvement in waterhemp control, especially at Moorhead which received 109-mm rainfall in June. These same treatments offered only modest improvement in waterhemp control at Blomkest which received only 20-mm rainfall in June. Soil residual herbicides with glyphosate and ethofumesate caused more sugarbeet injury than glyphosate and ethofumesate alone, despite only 20-mm + 20-mm of rainfall in May and June at Blomkest. However, injury became less over time and was negligible 30 to 65 day after planting across herbicide treatments.

Acifluorfen to Control *Amaranthus* spp. Escapes in Sugarbeet. Thomas J. Peters*[1], Emma L. Burt[2], Alexa L. Lystad[1]; [1]North Dakota State University, Fargo, ND, [2]Minn-Dak Farmers Cooperative, Wahpeton, ND (149)

Sugarbeet (*Beta vulgaris* L.) tolerance and waterhemp [*Amaranthus tuberculatus* (Moq.) J.D. Sauer] control with POST acifluorfen applications was investigated in 2019 and 2020. Two outcomes of this research were, first, acifluorfen applied at 0.28 kg ha^{-1} should be timed to 6-lf or greater sugarbeet. Acifluorfen applied before the 6-lf stage causes necrosis and stature reduction injury that reduces root yield (Mg ha^{-1}) and recoverable sucrose (kg ha^{-1}). Second, sugarbeet tolerance or waterhemp control from acifluorfen is influenced by adjuvant type or herbicide mixture with acifluorfen. We observed greater waterhemp control from acifluorfen mixtures with glyphosate, clopyralid, and / or ethofumesate than from acifluorfen, glyphosate, clopyralid, or ethofumesate alone. Previous research indicates acifluorfen postemergence provides effective control of other broadleaf weeds including kochia [*Bassia scoparia* (L.) A. J. Scott], redroot pigweed (*Amaranthus retroflexus* L.), Palmer amaranth (*Amaranthus palmeri* S. Watson), and Pennsylvania smartweed [*Persicaria pensylvanica* (L.) M. Gomez]. Will acifluorfen integrated into our waterhemp management strategy increase sugarbeet injury? Field experiments conducted across multiple environments in 2021 evaluated sugarbeet tolerance from acifluorfen as a component in a weed management program. Sugarbeet tolerance from glyphosate at 1.10 kg ha^{-1} with *S*-metolachlor and ethofumesate at 1.07, and 0.21 kg ha^{-1}, respectively, at the 2- and 8-lf stage; glyphosate at 1.10 kg ha^{-1} with *S*-metolachlor and ethofumesate at 1.07, and 0.21 kg ha^{-1}, respectively, at the 2-lf stage followed by (fb) glyphosate with acifluorfen at 1.10 and 0.28 kg ha^{-1}, respectively, and *S*-metolachlor at 1.07 kg ha^{-1}, at the 8-lf stage were compared with glyphosate at 1.10 kg ha^{-1} at the 2- fb 8-lf stage. Treatments were with or without *S*-metolachlor plus ethofumesate preemergence at 0.54 and 1.12 kg ha^{-1}, respectively. Preemergence applications did not affect sugarbeet stature, root yield, % sucrose, or recoverable sucrose. Stature reduction occurred with all treatments as compared with the glyphosate check 7 DAA (days after application); however, treatments with acifluorfen had up to 50% sugarbeet injury. Stature reduction was less 14 and 21 DAA; however, treatments with acifluorfen had up to 35% sugarbeet stature reduction at 21 DAA. Stature reduction translated into yield parameters. Acifluorfen treatments had root yield and recoverable sucrose significantly less than the glyphosate control or the glyphosate with *S*-metolachlor and ethofumesate waterhemp control treatment. Treatments did not affect % sucrose. These results indicate that acifluorfen applied as part of a weed management program will reduce sugarbeet stature, root yield and recoverable sucrose. Acifluorfen must be applied either alone or with glyphosate, postemergence, and without S-metolachlor and ethofumesate for sugarbeet tolerance.

Evaluation of the Seed Terminator^{TM} as a Harvest Weed Seed Control Tool in Missouri Soybean Production. Travis R. Winans*, Mandy Bish, Kevin W. Bradley; University of Missouri, Columbia, MO (150)

The distribution of herbicide resistant weeds such as waterhemp (*Amaranthus tuberculatus*) has resulted in a greater need for a more integrated approach to weed management, especially in U.S. soybean (*Glycine max* (L.) Merr.) production systems. Previous research in Australia has shown that harvest weed seed control can be a successful method to reduce weed seed from returning to the soil. One form of harvest weed seed control is the use of impact mills to destroy weed seed exiting the combine during grain harvest. One of the most common impact mill implements commercially available in Australia is called the Seed Terminator^{TM}. In 2019 and 2020, we investigated the efficacy of the Seed Terminator^{TM} installed on a Case IH 8250 combine in five different Missouri soybean fields that contained significant waterhemp infestations. Results indicate that 22% to 40% of the available waterhemp seed is lost to the soil due to shatter whenever the combine head comes into contact with the waterhemp plant at the time of harvest. Of the remaining seed that is directed into the combine, 51 to 78% is directed into the Seed Terminator^{TM} and 94% of that seed becomes significantly damaged. For two of the five locations, we were able to evaluate the effects of consecutive seasons of use of the Seed Terminator^{TM} on the same field. Both locations experienced a significant reduction of waterhemp in the soil seedbank by the spring following harvest. We were also able to determine that engine load was 12.6% higher, fuel consumption was 11.24 liters/hour greater, and harvest proceeded 0.40 kilometers/hour slower whenever the Seed Terminator^{TM} was engaged. Results from this research indicate that the use of impact mills could have a role in reducing soil weed seedbanks in at least the Midwest region of the United States in the future.

Testing Redekop™ Seed Destructor to Combat Herbicide-Resistant Weeds in Iowa Soybean Fields. Alexis L. Meadows*, Prashant Jha, Ramawatar Yadav, Avery J. Bennett, Edward S. Dearden, Ryan Hamberg, Austin H. Schleich; Iowa State University, Ames, IA (151)

NO ABSTRACT SUBMITTED

Characteristics and Performance of a Novel Deposition and Drift Reducing Adjuvant.
Gregory K. Dahl*[1], Ryan J. Edwards[2], Ryan Wolf[3], Joshua Mayfield[4], Joshua J. Skelton[5], Steven A. Fredericks[2], Christine Colby[2], Eric P. Spandl[2], Kevin Krueger[6]; [1]Winfield United, Eagan, MN, [2]WinField United, River Falls, WI, [3]Winfield United, Sheldon, IA, [4]Winfield United, Four Oaks, NC, [5]WinField United, Saint Paul, MN, [6]Winfield United, Arden Hills, MN (152)

Winfield United developed UltraLock™, a new adjuvant product that combines the functions of drift reduction technology, DRT, adjuvants with the functions of drift reduction adjuvants, DRA. DRT adjuvants were convenient to use and effective for increasing deposition, coverage, and canopy penetration, while reducing off-target particle drift with many herbicides. DRT adjuvants did not reduce spray particle drift sufficiently when used alone with the new dicamba formulations and nozzles. DRA adjuvants were developed for use with the new dicamba formulations and nozzles required, but they were viscous, inconvenient to handle, and had coverage limitations. Winfield United determined that spray particle drift could be further reduced by tank mixing DRT adjuvants with DRA adjuvants. This required two products to be added to the spray mixture. UltraLock was developed to combine the DRA adjuvant technology with the DRT technology into a single product. Research was conducted in wind tunnels, laboratories, greenhouses and in the field to determine droplet sizes, deposition and coverage and field performance. Spray analysis demonstrated that UltraLock reduced the volume and number of small driftable spray droplets more than with a DRA adjuvant alone and similar to a DRA plus DRT adjuvant system. Laboratory studies demonstrated that UltraLock was compatible with many herbicide spray mixtures and product poured quicker, more easily and more completely than DRA adjuvants. Greenhouse and field studies determined that deposition, spray coverage and herbicide performance were improved compared to herbicide alone and was better than or equal to performance of herbicide plus commercial adjuvants.

Integrated Weed Management in 2,4-D and Isoxaflutole-Resistant Soybeans in Kansas.
Chad J. Lammers*, Malynda M. Smith, Tyler P. Meyeres, Kraig L. Roozeboom, Sarah Lancaster; Kansas State University, Manhattan, KS (153)

Integrated weed management practices, including narrow row-spacing and overlapping residual herbicides, are needed to properly manage herbicide-resistant weeds. However, herbicide traits influence weed management options. Experiments were conducted to evaluate weed management in two herbicide resistant soybean varieties: 2,4-D-, glyphosate-, and glufosinate-resistant and isoxaflutole-, glyphosate-, and glufosinate-resistant planted in 36- and 78-cm row spacing at one location during 2020 and 3 locations during 2021. Three herbicide treatments were evaluated in each system: pre-emergence herbicide only (PRE), PRE followed by early post-emergence (POST), and POST plus overlapping residual (POR). PRE treatments were isoxaflutole (105 g ai ha^{-1}) plus pyroxasulfone (146 g ai ha^{-1}) in isoxaflutole-resistant soybeans or sulfentrazone (280 g ai ha^{-1}) and pyroxasulfone (146 g ai ha^{-1}). POST treatments were glufosinate (655 g ai ha^{-1}) plus ammonium sulfate (3,351 g ai ha^{-1}) or glufosinate (655 g ai ha^{-1}) plus ammonium sulfate (3,351 g ai ha^{-1}) plus 2,4-D at (1064 g ai ha^{-1}). The same POST herbicides with *S*-metolachlor (1419 g ai ha^{-1}) comprised POR treatments. Weed control was evaluated every 2 weeks after the application of the PRE herbicide until R7 soybean. Weeds evaluated at Manhattan during 2021 were ivyleaf morningglory (*Ipomoea hederacea* Jacq.*)* and Palmer amaranth (*Amaranthus palmeri* S. Watson*)*. In Ottawa, Venice mallow (*Hibiscus trionum* L.) and common waterhemp (*Amaranthus tuberculatus* (Moq.) J. D. Sauer*)* were evaluated during 2020 and 2021. Weed biomass was collected before the POST application and at R7 soybean. The center two rows of the plots were harvested, and yields adjusted to 13% moisture. Data were subjected to analysis of variance (a = 0.05) and means separation (Tukey's pairwise comparisons) using the packages lmer, anova, and emmeans in R. Differences among herbicides were noted in Ottawa during 2020 and for Palmer amaranth in Manhattan. When pooled across all species evaluated, POST and POR herbicides at Ottawa during 2020 resulted in $\geq$ 99% weed control 4 WAT in 2020 while PRE resulted in $\geq$84%. No differences were noted among treatments at Scandia during 2021, with all treatments resulting in $\geq$ 95% control. These data confirm that herbicide programs that include POST applications are superior to PRE-only programs, regardless of row spacing in the two soybean varieties evaluated. Additionally, the inclusion of a layered residual herbicide did not improve weed control over POST treatments with no residual control. However, this research did not evaluate the impact of layered residual herbicides on the weed seed, which is crucial for long-term weed management.

Utilizing Preemergence Herbicides to Maximize the Value of Machine-Vision Application Technology. Dane L. Bowers[1], R Joseph Wuerffel[2], Jason W. Adams[3], Pete Berry*[4]; [1]Syngenta Crop Protection, Greensboro, NC, [2]Syngenta Crop Protection, Gerald, MO, [3]Syngenta Crop Protection, Fargo, ND, [4]Syngenta Crop Protection, Monticello, IL (154)

Machine-vision precision application technology has enabled targeted applications of non-selective herbicides in non-crop situations (green-on-brown; GoB) commercially for several years. Recent advancements in machine-vision and sprayer technologies (e.g. pulse width modulation, single nozzle control) now allow for targeted applications to occur in major row crops with selective herbicides (green-on-green; GoG). This GoG technology has the potential to reduce the total amount of herbicide sprayed on a given field for major rows crops such as corn, soybeans, and cotton, especially in postemergence applications. However, it is unclear how weed pressure at the timing of postemergence applications will impact herbicide savings realized by the grower. This presentation aims to present preliminary data demonstrating the value that GoG technology, combined with robust preemergence herbicides (full use rates and multiple effective modes of action), may bring to growers in the future. Furthermore, this presentation will posit questions about the additional benefits (beyond herbicide savings) that the combination of GoG technology and robust residual weed control may bring, such as improved herbicide resistant weed management.

Spatial Variability of Soil Properties Influencing Soil Residual Herbicide Rates Within Indiana Commercial Fields. Rose V. Vagedes*, Bryan G. Young, William G. Johnson; Purdue University/, West Lafayette, IN (155)

Despite the advancements made to site-specific management practices, most herbicide applications are still being applied at a uniform rate across a field. Currently, the commercially available and developmental technologies for site-specific weed management (SSWM) have been focused on foliar-applied herbicides, with negligible attention on the utility of SSWM practices with soil residual herbicides. Organic matter (OM), soil texture, and pH can largely vary in a single field, all of which influence residual herbicide application rates. The implementation of SSWM with residual herbicides could help optimize herbicide efficacy while reducing the likelihood for crop injury. However, the feasibility of this practice needs to be justified and validated in commercial fields. Therefore, a survey was conducted to document the extent of variability in soil properties across commercial fields to justify site-specific soil residual herbicide applications. Additionally, a comparison was conducted between soil residual herbicides to determine if the variability of soil properties within ten different commercial Indiana fields was diverse enough to create two or more prescription zones for the herbicides of interest. These zones were developed using three different sources of spatial soil data: i) publicly available soil data provided by the USDA-NRCS Web Soil Survey (WSS), ii) collected soil samples regressed onto soil electrical conductivity (EC) measurements using regression kriging, and iii) ordinary kriging with collected soil samples. Semi-continuous, soil EC data was collected using a vehicle-mounted, electrical resistivity sensor followed by the collection of 60 soil samples using traditional sampling methods in a stratified random sampling pattern for all commercial fields. The soil texture and organic matter values predicted by WSS were compared to the lab results collected from the field samples. The WSS accurately predicted the soil texture at 36% of the sampling sites. However, when soil textures were grouped by coarse, medium, and fine texture classes based on herbicide labels, the WSS data accurately classified 62% of the sampling points. Additionally, the WSS organic matter levels were not consistent with the soil lab results. The maps developed from regression and ordinary kriging calculated similar total area (m^2) values for each application rate zone. The number of zones identified by the WSS maps and the size of each zone varied drastically from the respective kriged maps for several fields. For all fields, variability was extensive enough to require one or more application rates for all or some of the residual herbicides studied. Our research validates the inherent variability of soil parameters used for determining soil residual herbicide rates and justifies variable rate soil applications as a component of site-specific weed management. However, a lack of georeferenced soils data or predictive tools to develop prescription maps for the application of soil residual herbicide is a current limitation that requires further exploration.

Reduced Herbicide Antagonism Using a Dual Tank Delivery System for Volunteer Corn Control. William L. Patzoldt*; Blue River Technology, Sunnyvale, CA (156)

Abstract. Management of volunteer corn (*Zea mays*) in soybean (*Glycine max*) production is an annual problem in corn and soybean rotations. Some herbicide combinations involving group 1 herbicides used for control of volunteer corn, however, are known to have reduced activity due to antagonism. In this experiment, the objective was to determine if volunteer corn control could be improved if the group 1 herbicide component (e.g., clethodim) were applied separate from other herbicides known to cause antagonism. A field trial was established in Greenville, MS using a soybean variety resistant to dicamba, glyphosate, and glufosinate. Immediately after sowing soybeans, corn was hand seeded into each of the plots at a rate of 0.25 seeds m^{-2}. All plots, except for an untreated control, received a PRE herbicide application containing a premix of *s*-metolachlor plus metribuzin at 1920 g ai ha^{-1} and paraquat at 560 g ai ha^{-1}. The POST herbicide program consisted of dicamba at 560 g ae ha^{-1} plus glyphosate at 870 g ae ha^{-1} plus *s*-metolachlor at 1420 g ai ha^{-1} plus various rates of clethodim at either 26, 51, or 102 g ai ha^{-1}. Clethodim at different rates were applied using either a single tank mixture with dicamba, glyphosate, and *s*-metolachlor, or combined with *s*-metolachlor in one tank and separated from dicamba and glyphosate in a second tank (i.e., dual tank). When herbicide treatments were applied using a dual tank system, the two mixtures were kept separate all the way through the nozzle tips with the clethodim plus *s*-metolachlor mixture applied 8.6 cm before the dicamba plus glyphosate mixture. Visual percent volunteer corn control ratings taken 24 DAT suggested a dual tank system always resulted in higher performance than a single tank mixture for each rate of clethodim. For example, the only commercially successful treatment was using clethodim at 102 g ai ha^{-1} in a dual tank system with 98% visual volunteer corn control, whereas the single tank comparison treatment using the same rate of clethodim only provided 80% visual control. The control of Palmer amaranth (*Amaranthus palmeri*) or barnyardgrass (*Echinochloa crus-galli*) was not influenced by application technique and all POST herbicide treatments provided 100% control. The results of this study suggest a dual tank delivery system can be used to separate herbicide mixtures with known antagonism and provide improved performance.

Impact of Weed Density on Foliar Herbicide Efficacy. Tomas F. Delucchi*, Bryan G. Young, William G. Johnson; Purdue University, West Lafayette, IN (157)

Weed density can significantly affect foliar herbicide applications. Higher weed densities make postemergence herbicide failure more likely and this might be because of overlapping leaves causing insufficient spray deposition to reach all plants. Plant growth can also be affected directly through alterations in the spectral intensity of light caused by proximity of other plants. Low R:FR as detected by the phytochromes influence the whole plant morphology, including increased stem length and assimilate partitioning towards the stem. Low R:FR increases apical dominance and reduces basal branching. Plants growing in high densities have less overall leaf area to intercept the spray solution. Unsatisfactory weed control following a postemergence herbicide application can be expressed as compensatory growth from axillary buds and the application of non-systemic herbicides can break apical dominance and release previously dormant axillary buds. Two separate field trials and greenhouse studies were conducted with the objective of quantifying spray deposition and herbicide efficacy on tall waterhemp [*Amaranthus tuberculatus (Moq.)* J. D. Sauer] growing in three different densities: low, low-thinned and high densities. The low-thinned density was allowed to grow at the high density, but thinned down to an isolated plant the day before spraying to simulate growth in a high density, but without competing leaf overlap at the time of application. A second objective was to determine if tall waterhemp response is different for a non-systemic (glufosinate) versus a systemic (dicamba) herbicide under these three densities. In both field and greenhouse studies, spray deposition (µl cm^{-2}) on weeds growing in high density was at least 27% lower than on weeds growing in the low and thinned densities with no differences between herbicides. These differences were expected and have been cited as the cause of reduced efficacy of postemergence herbicides applied to dense weed infestations. In field and greenhouse studies, the highest efficacy with glufosinate, measured as proportional biomass reduction compared to the nontreated, was achieved on low density plants. Lateral branching in the lower stem was only observed with this low density treatment. Greater efficacy of glufosinate on isolated plants with lateral branching may suggest the dormant axillary buds present on plants for the other two density treatments allow for regrowth following glufosinate applications. Dicamba efficacy was similar across all three densities in the field and, since greater spray deposition was observed on thinned and low density plants compared to the high density ones, the systemic activity of dicamba may have compensated for less spray solution interception. In greenhouse studies, plants growing in high density were less affected by dicamba than plants growing in low and thinned densities. These results suggest that actively growing axillary meristems, eliciting branching from the lack of proximity to other plants, may have become more prominent herbicide sinks. Herbicide efficacy may be influenced by more than just differences in spray deposition from the presence or absence of adjacent plants. Our research suggests postemergence herbicide efficacy is influenced by spray deposition and the interaction of weed density and weed growth related to lateral branching from lower nodes.

Evaluation of a Low Speed Wind Tunnel for Simulating Boom-Scale Pesticide Spray Drift in Field Application Conditions. Elizabeth R. Alonzi, Aszhia K. Albrecht, Steven A. Fredericks*; Winfield United, River Falls, WI (158)

In agricultural spray applications off-target motion of applied pesticide droplets, also known as drift, has negative environmental and health impacts, as well as reduces the efficacy of the application. This can contribute to lower crop yields due to increased pest pressure and the development of weed resistance. Numerous methods have been developed to mitigate this spray drift and keep applied pesticides within the intended application area. Validating the effectiveness of these methods has historically required either field scale drift trials, which are costly and difficult to perform; or by extrapolating drift risk from the spray droplet size distributions measured in an idealized lab environment, which may neglect realities of field spraying. Herein, we present the evaluation of a newly constructed, low speed wind tunnel designed to mimic the spraying conditions typical of field application. In this study, multiple droplet samplers were positioned 1.5, 6, and 10.5 m downwind of a section field sprayer boom to measure air entrained droplets at heights of 0.25, 0.75, and 1.25 m. The droplets were marked with a fluorescent tracer which allowed for quantitative fluorometric measurement of the entrained mass flux of drifting droplets. These measurements were repeated for wind speeds between 2.2 and 6.7 m/s and for tank mixtures containing the tracer alone and in conjunction with a drift control adjuvant. The tunnel measurements were then compared against results from the same samplers measuring at the same position downwind of a field sprayer driving adjacent to plots while logging the ambient wind. When interpolating the tunnel spray flux to match the measured wind speed from the field measurements, the spray flux was found to be well correlated indicating that the low speed wind tunnel is a useful tool for evaluating drift.

Impact of Electrocution on Weed Control and Weed Seed Viability in Soybean. Haylee E. Schreier*, Travis Winans, Jake Vaughn, Delbert Knerr, Mandy Bish, Kevin W. Bradley; University of Missouri, Columbia, MO (159)

The predominance of herbicide-resistant weeds in U.S. agriculture has led to an interest in nonconventional methods of weed control, including weed electrocution. In the summer of 2020 and 2021, the Weed Zapper^{TM} was used to test the effectiveness of electrocution on several weeds commonly encountered in Midwest soybean production. In one experiment, waterhemp [(*Amaranthus tuberculatas* (Moq.)], common cocklebur (*Xanthium strumarium* L.), giant ragweed (*Ambrosia trifida* L.), common ragweed (*Ambrosia artemisiifolia* L.), horseweed (*Erigeron canadensis* L.), giant foxtail (*Setaria faberi* Herrm.), yellow foxtail [(*Setaria pumila* (Poir.)], and barnyardgrass (*Echinochloa crus-galli* L.) were electrocuted once plants reached 30.5 cm, 61 cm, flowering, pollination, and seed set. Each of the electrocution treatments took place at either 3.2 or 6.4 km/h and either once or twice sequentially one week after the first timing. Results from this experiment indicate that better control was achieved when weeds were taller, as this is when more of the plants were able to be contacted by the electrocution boom. Better control was also observed on broadleaf weeds compared to grasses. Additionally, fewer waterhemp plants recovered following electrocution with sequential passes compared to only one electrocution event. Along with the effects on weed control, seeds that were present at the time of electrocution were tested for viability. Results from the 2020 experiments indicate that viability was reduced on all species tested. A separate experiment was conducted to determine the effects of electrocution on potential soybean injury and yield loss. This was accomplished by having the electrocution boom maintain nearly constant contact with the upper 8 cm of the soybean canopy at V5, R1, R2, R3, R4, R5, and R6 soybean growth stages. In 2020, up to 18% soybean visual injury occurred following electrocution at the R3 timing, and this correlated with a 23% yield loss. However, this likely represents a worst-case scenario as growers that have a clear height differential between waterhemp and the soybean canopy will not need to maintain constant contact with soybean plants. Overall, results from this research indicate that weed electrocution shows promise as a late season rescue treatment in soybean.

Influence of Adjuvants on Canopy Deposition and Drift with UAV Application. Lee Boles A. Boles*, Ryan J. Edwards, Steven A. Fredericks, Laura Hennemann; WinField United, River Falls, WI (160)

Unmanned aerial vehicle (UAV) spray applications are becoming a more popular application method to apply agriculture sprays. However, there are many questions around best application practices and effectiveness of the spray UAVs. One question is how do adjuvants influence canopy deposition and drift? A study was performed to assess different spray adjuvant classes to see which best performed with a DJI AGRAS MG1P octocopter. The applications were made over tasseling corn with four drop nozzles, below the rotors. Water sensitive cards were placed at four levels within the canopy at three locations per plot, with three replications. Spray cards were also placed downwind from the application to track movement of spray droplets. The cards were then analyzed for droplet number, size and coverage. Adjuvants higher in oil content showed increased droplet deposition and canopy penetration.

Adoption of UAVs for Pest Management. Emma L. Gaither*, Reid Smeda; University of Missouri, Columbia, MO (161)

Traditional herbicide applications for industrial vegetation management (IVM) have predominantly relied upon ground-based equipment. However, this equipment is limited for usage on tall crop canopies, such as brush, and for aquatic species. Development of unmanned aerial vehicles (UAVs) allow reliable application in IVM situations. This research focused on a comparison between UAV and backpack applications for foliar herbicide activity on phragmites (*Phragmites australis*), a major aquatic weed that has invaded shallow wetlands in the central and eastern US. Treatments including glyphosate (0.744 kg ai · ha^{-1}), glyphosate (0.744 kg · ha^{-1}) plus florpyrauxifen-benzyl (0.029 kg · ha^{-1}), imazapyr (0.28 kg · ha^{-1}), imazapyr (0.28 kg · ha^{-1}) plus florpyrauxifen-benzyl (0.029 kg · ha^{-1}), and glyphosate (0.372 kg · ha^{-1}) plus imazapyr (0.14 kg · ha^{-1}) were applied at 149.8 L·ha^{-1}. An untreated control was also included. In 2020, applications were made in north-central MO and west-central IL at two timings: early August and late September. The applications made at the later timings were made at locations that had been previously mowed. Rhizomes were collected in November 2020. Thirty nodes were placed in flats of a 70:30 promix:field soil mix, fertilized weekly, and allowed to grow for 6 weeks. After 6 weeks, above ground biomass was collected. Imazapyr (0.28 kg · ha^{-1}) plus florpyrauxifen-benzyl (0.029 kg · ha^{-1}) had the lowest dried biomass (21% of control) and all treatments were at least 44% lower than the untreated control. Phragmites control was rated (0-100) one year after treatment (1 YAT). Imazapyr (0.28 kg · ha^{-1}), imazapyr (0.28 kg · ha^{-1}) plus florpyrauxifen-benzyl (0.029 kg · ha^{-1}), and glyphosate (0.372 kg · ha^{-1}) plus imazapyr (0.14 kg · ha^{-1}) showed the highest level of control; however, no treatment exceeded 70% 1 YAT. At both timings there was little difference in the method of phragmites treatment.

How Accurate Are Available Weather Resources for Pesticide Applicators? Comparisons Across Geographies. Mandy Bish*[1], Taylor Nix[1], Kevin W. Bradley[1], Nicholas J. Arneson[2], Nikola Arsenijevic[2], Maggie Ginn[3], Zachary S. Howard[4], Joseph Ikley[5], William G. Johnson[6], Jaime Knight[7], Sarah Lancaster[7], Lauren M. Lazaro[8], Travis Legleiter[9], Mark Loux[10], Scott A. Nolte[11], Bryan G. Young[6], Rodrigo Werle[2], Marcelo Zimmer[6]; [1]University of Missouri, Columbia, MO, [2]University of Wisconsin-Madison, Madison, WI, [3]Murray State University, Murray, KY, [4]Texas A&M University, College Station, TX, [5]North Dakota State University, Fargo, ND, [6]Purdue University, West Lafayette, IN, [7]Kansas State University, Manhattan, KS, [8]Louisiana State University AgCenter, Baton Rouge, LA, [9]University of Kentucky, Princeton, KY, [10]The Ohio State University, Columbus, OH, [11]Texas A&M AgriLife Extension, College Station, TX (162)

Favorable weather conditions are critical for successful pesticide applications. Synthetic auxin herbicide technologies have renewed interests in weather conditions at application. Specific interests include developing accurate weather-measuring instruments and predicting surface temperature inversions. New weather resources are available to address these matters. To validate new resources, we collected weather measurements using available mobile apps, web sites, and handheld devices. Air temperature, wind speed, and wind direction data were measured with each tool at state-maintained weather stations during the 2021 growing season. Data were collected at two locations in Missouri, and one location per state in Illinois, Indiana, Kansas, Kentucky, Louisiana, North Dakota, Ohio, Texas, and Wisconsin. Preliminary results indicate an average deviation of greater than 2 mph in wind speed and 2 degrees Fahrenheit in air temperature between each weather tool and weather station. Results also indicate that inversion forecasting tools are fairly accurate at some locations but not all, likely due to the effects of topography and microclimate. This study will provide relevant information for development and refinement of weather tools, which will enable pesticide applicators to make more informed decisions on which tools to utilize.

Hooded Broadcast Sprayer for Particle Drift Reduction. Rodrigo Werle*[1], Bruno Canella Vieira[1], Maxwel Coura Oliveira[1], Guilherme Sousa Alves[2], Jeffrey A. Golus[2], Kasey Schroeder[2], Reid Smeda[3], Ryan Rector[4], Greg Kruger[2]; [1]University of Wisconsin-Madison, Madison, WI, [2]University of Nebraska-Lincoln, North Platte, NE, [3]University of Missouri, Columbia, MO, [4]Bayer Crop Science, St Louis, MO (163)

There is renewed interest amongst crop protection professionals and regulators in the adoption of spray hoods to further reduce pesticide off-target movement during applications. Although the benefits of sprayer hoods were first reported in the early 1950's, adoption has been relatively low among farmers. The objective of this study was to evaluate the effectiveness of spray hoods in reducing pesticide drift for spray solutions with nozzles typically used for herbicide applications in row crops with resistance to dicamba or 2,4-D. Field experiments were conducted at North Platte (NE), Arlington (WI), and Columbia (MO) in 2020. Sprayer type (open and hooded), nozzle type (AIXR11003, TTI11003, and ULD12003), and spray solution (water with and without drift reducing adjuvant - DRA) were evaluated. A rhodamine fluorescent dye was added to all solutions at 0.5% v v^{-1}. Applications were made on mowed tall fescue (Missouri), fallow (Nebraska), and harvested corn stubble (Wisconsin) at 276 kPa with 140 L ha^{-1} carrier volume (10 replications per site*treatment). Drift collectors (Mylar cards) were placed downwind of the treated area in three transects spaced 7.6 m apart and perpendicular to the spray line. For each transect, 10 x 10 cm collectors were positioned at 1, 2, 3, 4, 8, 16, and 31 m downwind the treated area, whereas 20 x 20 cm collectors were positioned at 45 and 60 m. Four petri dishes (150 mm diameter) were placed in-swath to collect spray deposition. Samples were analyzed using fluorometry technique at the PAT Lab (University of Nebraska-Lincoln, West Central Research, Education, and Extension Center, North Platte, NE). Spray droplet size of treatments were analyzed using laser diffraction technique at the PAT Lab (3 replications per treatment). For the field study, spray drift and in-swath deposition (L cm^{-2}) were reported. The area under the spray drift curve (AUDC) was determined using the "agricolae" package in R statistical software. For the spray droplet size study, the D_{V10}, D_{V50}, and D_{V90} (droplet diameter such that 10, 50, and 90% of the spray volume is contained in droplets of lesser diameters, respectively) were reported along with the percentage of the spray volume with droplets <200 µm. Data analyses were performed with Bayesian inference with the "brms" package using R statistical software. Hooded applications substantially reduced spray drift potential across all treatment scenarios compared to conventional applications. Hooded applications using the AIXR nozzle without drift reducing adjuvant (DRA) had similar AUDC (31.5) compared to conventional applications (open sprayer) using the TTI nozzle with DRA (27.7), despite the major droplet size differences between these treatments (D_{V50} of 447.5 and 985 µm, respectively). These results indicate that the adoption of spray hoods combined with proper nozzle selection and the use of DRAs can substantially reduce spray drift potential during pesticide applications. Hooded sprayers could be an effective technique to mitigate spray drift during pesticide applications. The use of this technology can be complementary to other drift reducing technologies.

Diagnostics for ALS and Glyphosate Resistance in Michigan Soybean. Juliano R M Sulzback*, Erin C. Hill, Jinyi Chen, Eric L. Patterson; Michigan State University, East Lansing, MI (164)

Herbicide resistance to major herbicide modes of action (MOA) threatens sustainable row crop production. This is particularly true in row crops where the same MOA is applied year after like soybean. Michigan is the 13th largest soybean producing state and resistance is common in many of the most common weeds to the most common MOAs. The goals of this project are to sample the top 5 herbicide-resistant weed species from Michigan soybean fields; implement fast molecular diagnostic assays to detect the most common EPSPS and ALS inhibiting chemicals resistance mechanisms; and report that information to farmers in a timely fashion. Molecular diagnostic implementation can benefit growers immensely. Most importantly, these assays provide information about resistance in their fields, potential before they even have to spray, allowing them to develop weed management strategies within the growing season. Our sampling will have the added benefit of surveying where resistance is in these species to the MOAs across Michigan. Our work focuses on ALS-inhibitor resistance in common ragweed (*Ambrosia artemisiifolia*), Palmer amaranth (*Palmer amaranth*), marestail (*Erigeron canadensis*), waterhemp (*Amaranthus tuberculatus*) and giant ragweed (*Ambrosia trifida*) and EPSPS-inhibitor resistance in waterhemp and Palmer amaranth. Our results show that ALS resistance is common in all species and is caused by numerous SNPs in each species. Additionally, a majority of Amaranth samples have increased EPSPS copy number and most likely are resistant. Most surprisingly, published primers for ALS sequencing from these species are not universal and subtle changes in the genome sequence influences diagnostic efficiency.

The International Weed Genomics Consortium: a Resource for Weed Genomics. Sarah Morran*[1], Dana R. MacGregor[2], Eric L. Patterson[3], Joseph S. McElroy[4], Roland S. Beffa[5], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Rothamsted Research, Harpenden, United Kingdom, [3]Michigan State University, East Lansing, MI, [4]Auburn University, Auburn, AL, [5]Bayer Crop Science, Frankfort / Main, Germany (165)

NO ABSTRACT SUBMITTED

Glyphosate-resistant Johnsongrass (Sorghum Halepense) in Missouri: Potential Mechanisms of Resistance. Sarah E. Dixon*; University of Missouri, Columbia, MO (166)

A population of johnsongrass from northwestern Missouri with suspected glyphosate resistance (GR) was collected from agronomic fields in 2019. The 50% reduction in shoot weight (GR50) value for this population was 1414 g ae ha^{-1}, which was 5.3 times higher than the dose required for the susceptible (GS) population. Evidence for target-site resistance was examined by shikimic acid assay, reverse-transcription polymerase chain reaction (rt-PCR). For the shikimic acid assay, leaf discs collected from GR and GS johnsongrass were placed in glyphosate solutions, and shikimic acid exudation was quantified spectrophotometrically following incubation in the growth chamber for 24 hours. At glyphosate concentrations between 50 and 500 µM, up to 72% more shikimic acid was detected from the GS compared to GR population. At 1000 µM, shikimic acid levels were statistically similar. With rt-PCR, gene expression of 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase was quantified utilizing RNA extracted from frozen tissue samples of GR and GS johnsongrass. From the RNA template, first-strand complementary DNA (cDNA) was synthesized. Three unique primer pairs each for acetolactate synthase (ALS) as a reference gene as well as EPSP synthase as the target gene were loaded into the PCR reaction with SYBR green dye as the fluorescence signal to derive amplification efficiency using the QuantStudio 3 system. Gene expression was compared between GR and GS biotypes for ALS and EPSP synthase using the cycle number at the threshold level of log-based fluorescence (Ct) as the dependent variable for statistical analysis. Results indicate no significant differences in EPSP synthase expression between the two populations (p=0.1754). Non-target site resistance was also examined using radiolabeled glyphosate. GR and GS johnsongrass plants were treated with 10 µL of a solution containing ^{14}C-glyphosate in deionized water with formulated glyphosate at 868 g ae ha-1. Plants were harvested at 12, 24, 48, 72 and 96 hours after treatment (HAT) and partitioned after washing the treated leaf to remove unabsorbed glyphosate. No significant differences were observed for glyphosate absorption, with the GR population absorbing 0.1% more of the total applied radioactivity than the GS population. Significant differences in translocation between the two populations were observed at 96 HAT, with the GR population retaining 42% more activity in the treated leaf than the GS population, suggesting that reduced translocation may be the mechanism underlying resistance. Sequencing of EPSP synthase in the GR population is ongoing to determine if potential point mutations contribute to the resistance mechanism of this biotype.

Better Together: Bicyclopyrone and Mesotrione Enhance Weed Control in Acuron GT.
Ryan D. Lins*[1], Mark Kitt[2], David Stafford[3], Mark Johnston[3], Brian Pickett[3], Sunil Kumar[4]; [1]Syngenta Crop Protection, Rochester, MN, [2]Syngenta Crop Protection, Greensboro, NC, [3]Syngenta Crop Protection, Jealott's Hill, United Kingdom, [4]Syngenta Crop Protection, Basel, Switzerland (167)

Bicyclopyrone and mesotrione are HPPD inhibiting herbicides developed by Syngenta for use in corn production. This presentation outlines some of the work that has been done to characterize and support the combination of these two active ingredients in products such as Acuron GT® .

Understanding a New Mechanism of Dicamba-resistance in *Bassia scoparia*. Jacob S. Montgomery*[1], Neeta Soni[1], Sarah Morran[1], Eric L. Patterson[2], Philip Westra[1], Franck E. Dayan[1], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Michigan State University, East Lansing, MI (168)

The recent introduction of genetically modified crops resistant to dicamba has increased the usage of dicamba in agricultural settings. This increase has caused accelerated evolution of dicamba resistance in weedy species due to increased selection pressure. A dicamba-resistant population of *Bassia scoparia* (M32) collected from Akron, Colorado was identified in an herbicide resistance survey conducted in 2012. Dose response studies confirmed dicamba resistance within M32 (R:S 11) of approximate equal magnitude conveyed by the previously reported G127N mutation of *IAA16* (R:S 15). Sanger sequencing of 58 dicamba-resistant M32 plants revealed the absence of the G127N substitution in the *IAA16* gene. Populations segregating for dicamba resistance were produced via a bi-parental cross between individuals of M32 and a dicamba-sensitive reference population (7710). Approximately 300 plants each from two segregating F3 families were screened with a delimiting rate of dicamba (560 g ae ha^{-1}). Ratios of alive and dead plants suggest dicamba resistance was simply inherited. A newly developed genotype-by-sequencing protocol was used on individuals from these segregating populations to identify QTL underlying this trait. Quantification of absorption and subsequent translocation of radiolabeled dicamba applied to plants from M32, 7710, and a population homozygous for the G127N substitution of *IAA16* indicated that differential absorption of dicamba is not associated with resistance. However, both M32 and the known resistant line showed reduced dicamba translocation out of the treated leaf. Future work will focus on refining the list of - and functionally validating - candidate genes associated with dicamba-resistance in M32.

Heterologous Expression of CYPs from HPPD-resistant Palmer Amaranth (*Amaranthus palmeri*) in Yeast. Carlos Alberto Gonsiorkiewicz Rigon*[1], Crystal D. Sparks[1], Lennart Charton[2], Anita Küpper[3], Roland S. Beffa[4], Franck E. Dayan[1], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Bayer Crop Science, Frankfurt Am Main, Germany, [3]Bayer Crop Science, Frankfurt, Germany, [4]Bayer Crop Science, Frankfort / Main, Germany (169)

Cytochrome P450 monooxygenases (P450s) are heme-dependent proteins that catalyze phase I of metabolism for endogenous and some exogenous molecules by oxidation. Metabolism-based herbicide resistance in weeds is particularly troublesome due to the capacity of these enzymes to utilize herbicides from different chemical groups as substrates. A population of Palmer amaranth from Nebraska (NER) was characterized to be resistant to tembotrione due to faster hydroxylation than a susceptible population (NES). Hydroxylation is usually catalyzed by P450 enzymes. The objectives of the study were to: (1) use the RNA-seq performed on Pseudo-F2 to measure differential gene expression between tembotrione-resistant and susceptible F2 individuals, and (2) validate candidates P450s using a yeast system to provide evidence of tembotrione-hydroxylation by specific *CYPs*. RNA-seq analysis was performed using Pseudo-F2 tembotrione-resistant and -susceptible plants originated from two separate NER x NES crosses. The plants were sampled before, six, and twelve h after treatment (HAT). DESeq2 was used to identify differential gene expression. Yeast strains WAT11 and WAT21 harboring the genes for plant *P450-reductase* 1 or 2, respectively, were transformed with candidate CYPs using the expression plasmid pYES2. A known P450 from corn (*Nsf1*) that metabolizes tembotrione was used as a positive control. Transformed yeast lines were incubated for 24 h with tembotrione before the supernatant was collected and analyzed by LC-MS system (Shimadzu Scientific Instruments, Columbia, MD, USA). Three *CYP72A219*-like and one *CYP81E8*-like were identified as candidates for metabolic resistance. Normalized read count differences ranged from 5- to 18-fold change between NER and NES. These genes together with glycosyltransferases (*GTs*), glutathione-*S*-transferase (*GST*), and transcription factors were constitutively higher expressed in NER. qPCR analysis in parental plants confirmed the higher expression of these genes in NER. Hydroxy-tembotrione was detected in the supernatant from yeast transformed with *Nsf1* and from one version of *CYP72A219*-like. Metabolites had a peak at least three-fold higher than the background signal in the empty control. Dihydroxy-tembotrione was detected in the *Nsf1* transformant, but not in the *CYP72A219*-like transformant. No metabolites were detected in this expression system using the other two *CYP72A219*-like and *CYP81E*-like, but the involvement of these other genes in tembotrione metabolism *in planta* may not be dismissed based only on the negative result in a heterologous system. Docking studies were performed to assess the binding affinity of *Nsf1* and *CYP72A219-like* for tembotrione. This *CYP72A219*-like gene is involved in the metabolism of tembotrione in Palmer amaranth. The resistance trait may be multigenic and other P450s may be involved.

Proceedings Symbols
*Presenting Author

Evidence of Multiple Gene Inheritance of 2,4-D Resistance in Palmer Amaranth.
Chandrima Shyam*, Dallas E. Peterson, Mithila Jugulam; Kansas State University, Manhattan, KS (170)

A Palmer amaranth (*Amaranthus palmeri* S. Watson) population (KCTR: Kansas Conservation Tillage Resistant) in Kansas identified in a long-term conservation tillage field study was documented to have evolved metabolic resistance to at least five modes of action of herbicides, including 2,4-D, a synthetic auxinic herbicide. The KCTR Palmer amaranth rapidly metabolizes 2,4-D compared to two susceptible Palmer amaranth populations (KSS: Kansas Susceptible and MSS: Mississippi Susceptible). In this study, the genetic basis of 2,4-D resistance in KCTR was investigated. Direct and reciprocal crosses were performed using 2,4-D-resistant KCTR and susceptible KSS plants to generate three F_1 families, *i.e*., F_1-1, F_1-2, and F_1-3. 2,4-D dose-response assays were conducted to evaluate the response of progenies from each F_1 family along with parental resistant (KCTR) and susceptible (KSS) plants in controlled environmental growth chambers. Plants were treated with varying doses of 2,4-D ranging from non-treated to 4X (where 1X is the field recommended dose of 2,4-D which is 560 g ae ha^{-1}) and was repeated once. Above-ground shoots were harvested at 4 weeks after treatment (WAT) and dry weight was measured. Additionally, 2,4-D-resistant male and female plants from each of the F_1 families were crossed to generate pseudo-F_2 families. In total, four F_2 families were generated *i.e*., F_2-1, F_2-2, F_2-3-1, and F_2-3-2. Segregation (resistance or susceptibility) of progenies from the F_2 families in response to the field recommended dose of 2,4-D was evaluated. Analysis of dry weight data from the dose-response experiments of F_1 progenies derived from either direct or reciprocal crosses suggested that the F_1 progenies had an intermediate response to 2,4-D treatment relative to resistant and susceptible parents. Such response indicates that the 2,4-D resistance in KCTR is an incompletely dominant nuclear trait. Chi-square analyses of F_2 segregation data did not fit the Mendelian single gene segregation model (*i.e.,* 3:1 resistance:susceptibility), implying that 2,4-D resistance in KCTR is controlled by multiple gene(s). Moreover, significant variation in phenotypes among F_2 progenies treated with 2,4-D also corroborated the polygenic nature of 2,4-D resistance trait. Previously we have confirmed that 2,4-D resistance in KCTR is due to enhanced metabolism possibly mediated by cytochrome P450 enzyme activity. It is highly likely that either multiple P450 genes or P450 along with other genes may be governing the 2,4-D resistance in KCTR. Future efforts will be directed towards identifying the genes involved in mediating 2,4-D resistance in KCTR Palmer amaranth.

"The Effect of ΔG210 and R128G Mutations in Waterhemp on the Resistance Phenotype for Soil Applied PPO Inhibitors.". Jesse A. Haarmann*, Bryan G. Young, William G. Johnson; Purdue University, West Lafayette, IN (171)

The PPO inhibitors are a valuable group of herbicides that provide soil and foliar control of waterhemp (*Amaranthus tuberculatus* (Moq.) J.D.Sauer). The **Δ**G210 mutation in the PPX2 gene confers PPO inhibitor resistance and has been present in the Midwest for nearly two decades. Most PPO inhibitor resistance in waterhemp has been attributed to the **Δ**G210 mutation, with more recent confirmation of the R128 mutations in several populations throughout the Midwest. Given the already widespread distribution and robust resistance phenotype of the **Δ**G210 mutation, the latent evolution of the R128 mutations remains unclear. We hypothesized that either the soil applied PPO inhibitor use pattern or specific active ingredients that are applied primarily preemergence are selecting for novel PPO inhibitor resistance conferring mutations. We conducted a series of dose response experiments in the greenhouse on waterhemp homozygous for **Δ**G210, R128G, and susceptible PPX2 alleles. The herbicides flumioxazin, sulfentrazone, fomesafen, oxadiazon, saflufenacil and trifludimoxazin were applied to soil planted with waterhemp seeds. Emergence counts were used to fit Weibull type I dose response models for each herbicide. Both the R128G and **Δ**G210 mutations resulted in a significant resistance response for all herbicides tested including trifludimoxazin. The greatest resistance response observed was to fomesafen with a 20- to 37-fold resistance ratio followed by saflufenacil which had 10- to 15-fold resistance ratios. All other herbicides tested had resistance ratios less than 9 for both mutations. Sulfentrazone was the only herbicide which the R128G mutation had a greater resistance response than the **Δ**G210 mutation with a 0.48 **Δ**G210 to R128G ED_{50} ratio (4 vs 9 R/S ratios). Overall, the data do not support our hypothesis that the R128G mutation was selected for by soil applied PPO inhibitors. We conclude that the R128G mutation in waterhemp is not substantially different from the **Δ**G210 mutation with respect to resistance response. Furthermore, there is no evidence that the utility of PPO inhibitors applied PRE will diminish any further as a result of the R128G mutation increasing in frequency.

Fields to Genes After 36 Years of a Weed Science Career in Colorado. Philip Westra*; Colorado State University, Fort Collins, CO (172)

NO ABSTRACT SUBMITTED

The First Dicamba-Resistance Case in Waterhemp (*Amaranthus tuberculatus*): Inheritance Characterization and Identification of Candidate Resistance Genes from RNA-Seq. Lucas K. Bobadilla*[1], Darci Giacomini[2], Patrick Tranel[3], Aaron Hager[3]; [1]University of Illinois, Champaign, IL, [2]Invitae, Golden, CO, [3]University of Illinois, Urbana, IL (173)

Waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer) is one of the most troublesome weed species in the midwestern US. The rapid evolution and selection of herbicide-resistance traits in waterhemp is a major challenge in managing this species. A specific waterhemp population, designated CHR, was identified in 2012 in Champaign County, IL, after unsuccessful control with topramezone. CHR was subsequently characterized as resistant to Group 27 herbicides as well as to several other herbicides including 2,4-D and herbicides from Groups 2, 5, 14, and 15. Interestingly, the field history from which CHR was collected does not indicate the previous usage of 2,4-D, raising questions about potential resistance to other auxinic herbicides such as dicamba. Previous studies with CHR reported that dicamba, at the recommended field rate, provided 80% control. The lack of a more acceptable level of control prompted further investigation into potential dicamba resistance in this population. This study presents the characterization and inheritance patterns of dicamba-resistance and the identification of candidate resistance genes via RNA-seq in CHR. CHR-derived populations consisting of parental lines (R and S), F_1 lines (F_1), backcross (BC) lines, and a pseudo-F2 line (F_2) were generated. A dose-response experiment was conducted to characterize the level and degree of dominance of dicamba resistance. Plants were treated with nine dicamba rates: 0, 1.18, 3.92, 11.8, 39.2, 118, 392, 1,180 and 2,350 g ae ha^{-1}. Segregation analysis was conducted to quantify the inheritance of dicamba resistance. Dicamba damage was estimated using a machine learning approach. Sixteen F_2 plants (8 resistant and 8 susceptible) were further selected for RNA sequencing. Sequencing was done using Illumina NovaSeq 6000 - 1x100bp. A guided *De-novo* transcriptome assembly was done using Trinity and the waterhemp genome. Reads were pseudo-aligned to the transcriptome using Kallisto. Differential expression analysis was conducted at gene and transcript levels using EdgeR and Sleuth. An RT-qPCR assay was conducted to validate candidate genes from RNA-seq. Dose-response experiments indicated a resistance level of 5 to 10-fold, and that dicamba resistance was an incompletely dominant trait. Segregation analysis with F_2 and backcross populations indicated that dicamba resistance had moderate heritability and is a multigenic trait. Results identified a list of around 100 genes differentially expressed at the gene level and 65 genes at the transcript level. Among those genes, genes involved with auxin catabolism, ROS detoxification, auxin efflux, early auxin responses, and metabolic resistance were identified. Two candidate genes were confirmed as differently expressed from the RT-qPCR assay. Candidate genes point to a unique resistance mechanism in CHR with auxin transport reduction and ROS detoxification involvement. Further studies will focus on understanding the physiology behind this resistant mechanism and correlate it with other resistance traits present in CHR via QTL mapping.

TriVolt Herbicide: A New Residual Herbicide Combination for Weed Management in Corn. Eric Riley*; Bayer Crop Science, St. Louis, MO (174)

TriVolt™ is a new residual herbicide premix developed by Bayer CropScience for weed management in corn and is currently pending registration with the EPA. This product contains the following three active ingredients and the safener, cyprosulfamide: isoxaflutole, a Group 27 herbicide, thiencarbazone-methyl, a Group 2 herbicide, and flufenacet, a Group 15 herbicide. TriVolt will provide a resistance management option for corn growers with its combination of three different sites of action. In addition, this product will help provide broad spectrum and consistent weed control against common grass and broadleaf species in corn such as amaranths (*Amaranthus sp.*) and foxtails (*Setaria sp.*). Field studies were conducted in 2020 and 2021 to evaluate crop safety and residual weed control of TriVolt compared to Acuron® and Resicore® Herbicides. Atrazine was tank-mixed with TriVolt and Resicore and applications were made preemergence, at the time of planting. Overall, results from these studies indicate TriVolt can help provide excellent crop safety and consistent weed control. In both years, TriVolt provided similar levels of residual weed control compared to Acuron and improved residual grass control compared to Resicore, 56 days after treatment. With three different herbicide sites of action and a novel safener, TriVolt will be an effective, crop-safe and consistent weed management tool in corn.

Preemergence Weed Control in Corn with Resicore® XL. Kevin D. Johnson*, Joe Armstrong, Kristin Rosenbaum, Jeffrey T. Krumm, David M. Simpson; Corteva Agriscience, Indianapolis, IN (175)

Resicore® XL is a new premix formulation of acetochlor, mesotrione, and clopyralid for preplant, preemergence (PRE), and postemergence weed control in corn. Results from over 30 Corteva Agriscience research trials conducted from 2018 to 2021 have shown Resicore XL to have excellent crop safety, with <3% crop response observed with PRE applications at recommended label rates. Additionally, results from these trials have shown Resicore XL to provide >90% PRE control at 6 weeks after application of many key weeds, including giant ragweed (*Ambrosia trifida*), common waterhemp (*Amaranthus rudis*), Palmer amaranth (*Amaranthus palmeri*), common lambsquarters (*Chenopodium album*), and annual grasses across the Midwest and Southern US. Tank mixes with atrazine further improve control of key broadleaf weeds to >95% with PRE applications including giant ragweed, common waterhemp, and Palmer amaranth. Resicore XL also demonstrates improved mixing and handling characteristics allowing for ease of use with fertilizer solutions such as ammonium thiosulfate and urea ammonium nitrate. Corteva Agriscience plans to bring Resicore® XL to farmers in 2022, pending US Environmental Protection Agency approval. ™® Trademarks of Corteva Agriscience and its affiliated companies

Resicore XL® for Postemergence Weed Control and Two-Pass Programs in Corn. Joe Armstrong*, Kevin D. Johnson, Kevin Hahn, Dave Johnson, David M. Simpson; Corteva Agriscience, Indianapolis, IN (176)

Building on the success of Resicore® herbicide, Corteva Agriscience plans to bring Resicore® XL to farmers in 2022, pending US Environmental Protection Agency approval. Resicore XL is a new premix formulation of acetochlor, mesotrione, and clopyralid for preplant, preemergence (PRE), and postemergence (POST) weed control in corn. Formulated with encapsulated acetochlor, Resicore XL demonstrates improved mixing and handling and POST crop safety with a wide application window. Results from over 20 Corteva Agriscience research trials conducted from 2018 to 2021 have shown Resicore XL to have excellent crop safety, with <5% crop injury observed with POST applications. Additionally, results from these trials have shown Resicore XL to provide >90% POST control of many key weeds, including giant ragweed (*Ambrosia trifida*), common waterhemp (*Amaranthus rudis*), Palmer amaranth (*Amaranthus palmeri*), common lambsquarters (*Chenopodium album*), and annual grasses across the Midwest and Southern US. Tank mixes with atrazine and glyphosate further improve control. Resicore XL is also an effective component of a two-pass PRE followed by POST weed control program in corn. When used POST following a PRE herbicide application in corn, Resicore XL will provide >95% season-long control of many key weeds with extended residual control after application. With excellent crop safety, flexible application window, and proven efficacy on key weeds, Resicore XL will be an important tool for effective weed management in corn. ™® Trademarks of Corteva Agriscience and its affiliated companies

Bromoxynil + Fluroxypyr + Pyrasulfotole + Mefenpyr-diethly Combination Herbicide – Overview of Performance in Northern Plains Cereals. Kevin B. Thorsness*[1], Dean W. Maruska[2], Michael C. Smith[3], Brad Nemmers[4], Sarah V. Striegel[5], Ryan E. Rapp[6], Devin J. Hammer[7], Rory Cranston[8]; [1]Bayer Crop Science, Fargo, ND, [2]Bayer Crop Science, Warren, MN, [3]Bayer Crop Science, West Fargo, ND, [4]Bayer Crop Science, Dell Rapids, SD, [5]Bayer Crop Science, Madison, MN, [6]Bayer Crop Science, Mitchell, SD, [7]Bayer Crop Science, St. Louis, MO, [8]Bayer Crop Science, Calgary, AB, Canada (177)

Huskie® FX Herbicide is a new broad spectrum postemergence broadleaf herbicide that was introduced in 2021 by Bayer Crop Science. Huskie® FX Herbicide is registered in several states of the United States for use in spring wheat, durum, winter wheat, barley, and triticale. Huskie® FX Herbicide is a mixture of three broadleaf herbicides plus mefenpyr-diethyl, the highly effective cereal herbicide safener. The inclusion of three different herbicide sites of action, an HPPD, a PSII inhibitor, and an Auxin, provide a product with unique resistance management characteristics. Huskie® FX Herbicide is a consistent broad-spectrum broadleaf herbicide with excellent crop tolerance. Huskie® FX Herbicide is formulated as an emulsifiable concentrate for easy mixing and handling by the customer. The recommended use rate for Huskie® FX Herbicide is 13.5-18 oz ac^{-1}. Huskie® FX Herbicide should be applied after the cereal crop has fully developed the second leaf but before flag leaf emergence. Optimum control of broadleaf weeds and maximum yield is achieved when apply Huskie® FX Herbicide is applied between the 1 - 8 leaf weed stage of growth, or when weeds are less than 4 inches in diameter, depending on weed species. Huskie® FX Herbicide can be tank mixed with graminicides as well as selected fungicides and insecticides. When Huskie® FX Herbicide is applied alone it can be mixed with AMS at 0.5 lb ac^{-1} or with 28% UAN at 1 qt ac^{-1}. Huskie® FX Herbicide has been tested on broadleaf weed species at many locations in numerous field experiments from 2018-2021 in the northern cereal production area of the United States. Huskie® FX Herbicide controls key broadleaf weeds such as kochia, pigweed sp., wild buckwheat, common lambsquarters, mustard sp., Russian thistle, field pennycress, prickly lettuce, common waterhemp, white cockle, and nightshade sp. Huskie® FX Herbicide also controls sulfonylurea resistant weeds such as kochia, prickly lettuce and Russian thistle. Additionally, Huskie® FX Herbicide provides excellent control of glyphosate resistant kochia, common ragweed, and horseweed. Crop tolerance with Huskie® FX Herbicide has been excellent when tested on several different varieties of spring wheat, durum wheat, and barley. Based on internal sales information, Huskie® FX Herbicide was commercially applied on approximately 850,000 acres of cereals in the United States in 2021. Overall, weed control and crop tolerance with Huskie® FX Herbicide was excellent in 2021, in spite of being applied during some challenging environmental conditions. Huskie® FX Herbicide is the evolution of the Huskie® family of herbicides. These products have been relied upon by cereal growers since 2008. Excellent weed control, excellent crop safety, and a favorable crop rotation profile; make Huskie® FX Herbicide a valuable tool for wheat, barley, and triticale producers.

Reviton and Other New Herbicides from Helm. Brock S. Waggoner*[1], James Whitehead[2], Scott Akin[3]; [1]Helm Agro, Salem, IL, [2]Helm Agro, Oxford, MS, [3]Helm Agro, Murray, KY (178)

NO ABSTRACT SUBMITTED

Imazamox for Saltcedar Control. Walter H. Fick*; Kansas State University, Manhattan, KS (179)

Saltcedar (*Tamarix ramosissima*) is a deciduous shrub up to 8-m tall found throughout the Great Plains, southwest U.S. and several states in the southeastern U.S. Saltcedar occurs on open floodplains, shorelines of reservoirs and ponds, and salt marshes. In Kansas, saltcedar is distributed along the Cimarron, Arkansas, Smoky Hill, Republican, and Kansas rivers. The objective of this study was to compare the efficacy of imazamox with other herbicides previously studied for saltcedar control. The study site is located on the Cimarron National Grasslands located in southwest Kansas. Herbicides were applied on September 14, 2020. Environmental conditions during treatment were 16 to 28 ^{o}C, 42 to 89% relative humidity, and 0 to 0.9 m sec^{-1} wind speed. Herbicides were each applied to 12 to 15 plants using a backpack sprayer at 467 L ha^{-1}. Mortality was determined 1 year after application and differences in control determined using Chi Square analysis at the 0.05 level of significance. Plants with no leaves or resprouting were considered dead. All foliar applied herbicides including Imazamox at 6 g L^{-1} + 1% MSO, imazapyr at 4.8 g L^{-1} + 1% MSO, imazapyr + glyphosate at 2.4 + 2.7 g L^{-1}, imazapic at 2.4 g L^{-1} + 1% MSO, and aminopyralid + triclopyr at 0.13 + 3.4 g L^{-1} + 0.25% NIS provided 100% control of saltcedar. Triclopyr applied as a basal bark treatment in diesel at 48 g L^{-1} provided 62% control. Basal bark applications can be effective, but require that all stems be sprayed on all sides. Foliar treatments on saltcedar were excellent in 2020, with above normal precipitation received in July and August preceding herbicide application. All treatments were repeated in 2021.

Influence of Grazing on Red and White Clover Biomass in Rotationally Grazed Grass-Legume Pastures Treated with 2,4-D + Florpyrauxifen. Garrett N. Imhoff*[1], Mark J. Renz[1], Scott Flynn[2]; [1]University of Wisconsin-Madison,, Madison, WI, [2]Corteva Agriscience, Indianapolis, IN (180)

Florpyrauxifen-benzyl + 2,4-D is a new pasture herbicide that controls broadleaf weeds with limited injury to legumes. Previous studies indicate white clover (*Trifolium repens* L.) has higher tolerance than red clover (*Trifolium pratense* L.). Given red clover's frequency in pastures, interest in improving its tolerance to florpyrauxifen-benzyl + 2,4-D exist. Grazing near application timing may be one approach to increasing tolerance. We established separate experiments in pastures in 2020 and 2021 in Lancaster, Wisconsin to determine if red clover tolerance to florpyrauxifen + 2,4-D is improved by grazing near application. Pastures consisted of tall fescue (*Lolium arundinaceum* S.), orchardgrass (*Dactylis glomerata* L.) and equal populations of white clover and red clover. Weed species commonly found were dandelion (*Taraxacum officinale* L.), buckhorn plantain (*Plantago lanceolata* L.), and broadleaf plantain (*Plantago major* L.). Experiments were a split plot design replicated three times with grazing timing as the whole plot (0.2 ha) and herbicide treatment as the subplot. Applications of 0.1 g ae ha^{-1} of florpyrauxifen + 554 g ae ha^{-1} 2,4-D were broadcasted in spring (5/27/20, 5/27/21) to ½ of the whole plot, the other ½ was not treated. Seven grazing timings were evaluated. Treatments were either grazed 6, 4, or 2 days prior to application, the day of application, or 6 days after application. Time of grazing was implemented by rotational grazing approximately on 30 day intervals with a mix of bred heifers and cows at a stocking density of 10,648 kg ha^{-1}. Biomass was collected prior to each grazing interval to estimate productivity. Species were separated into red clover, white clover, broadleaf weeds, annual grass weeds and forage grasses. Biomass was dried and summed over the experiment (June-October). Comparisons were made between grazing timing, herbicide treatment, year and interactions, and considered significant if $P<0.05$. Grazing timing did not change biomass accumulation of any class, and year, while significant, did not interact with herbicide effects or grazing timing. While total biomass did not differ between treated and not treated areas (4,537 kg ha^{-1}), plant class biomass was impacted by florpyrauxifen + 2,4-D. Red and white clover yield was reduced by florpyrauxifen-benzyl + 2,4-D by 399 kg ha^{-1} and 376 kg ha^{-1} respectively, a 56% and 44% reduction respectively, when compared to untreated controls. Florpyrauxifen + 2,4-D also reduced broadleaf weed biomass by 83%, however forage grass and annual weedy grass biomass both increased by 16% and 42%. Results suggest that grazing does improve red clover tolerance as biomass is reduced but not eliminated when florpyrauxifen + 2,4-D is applied and grazed within six days before or after application. Clover and broadleaf weed forage loss due to herbicide application were compensated by increases in forage grass biomass. Applications of florpyrauxifen-benzyl + 2,4-D may benefit grass-legume pastures if forage grasses can overcome the clover and weed biomass reduction without impacting forage quality.

2021 Survey Results for the Most Common and Troublesome Weeds in Aquatic and Non-Crop Areas. Lee Van Wychen*[1], Devon Carroll[2], Rebecca Champagne[3]; [1]WSSA, Alexandria, VA, [2]University of Tennessee, Knoxville, TN, [3]University of Maine, Orono, ME (181)

The 2021 Weed Survey for the U.S. and Canada surveyed the most common and troublesome weeds in: 1) irrigation and flood control; 2) lakes, reservoirs, and rivers; 3) ponds; 4) forestry; 5) parks and refuges; 6) ornamentals: field nursery crops, outdoor containers, and Christmas trees; and 7) rights-of-way: railways, roads, public utilities. Common weeds refer those most frequently seen while troublesome weeds are the most difficult to control, but not necessarily widespread. There were 289 total survey responses from the U.S. and Canada, of which 68 were from 13 states and one province in the North Central Weed Science Society (NCWSS) region. There was no survey data submitted from Illinois, North Dakota, and South Dakota. Among the 13 states and 1 province in the NCWSS region, the two most common weeds in irrigation and flood control were 1) *Stuckenia pectinata*; and 2) *Lythrum salicaria*, while the most troublesome weed was 1) *Lythrum salicaria*. The top three most common weeds in lakes, reservoirs and rivers were 1) *Potamogeton* spp.; 2) *Myriophyllum* spp.; and 3) *Ceratophyllum demersum*, while the three most troublesome weeds were 1) *Myriophyllum* spp.; 2) *Potamogeton crispus*; and 3) *Nitellopsis obtuse*. The top three most common weeds in ponds were 1) *Potamogeton* spp.; 2) *Ceratophyllum demersum*; and 3) *Typha* spp. while the two most troublesome weeds were 1) *Wolffia* spp.; and 2) *Potamogeton* spp. Among terrestrial areas in the 13 states and 1 province in the NCWSS where weed survey data was submitted, the top three most common weeds in forestry were 1) a tie between *Cirsium arvense* and *Carduus nutans*; and 3) *Cynoglossum officinale* while there was a five-way tie for most troublesome weed including *Carduus nutans*, *Celastrus orbiculatus, Cirsium arvense*, *Cynoglossum officinale*, and *Linaria vulgaris*. The top three most common weeds in parks and refuges were 1) *Bromus* spp.; 2) *Cirsium arvense*; and 3) *Carduus nutans* and the most troublesome weed 1) *Cirsium arvense* followed by a six-way tie. The two most common and troublesome weeds in ornamentals were tied between *Cirsium arvense* and *Convolvulus arvensis*, but survey data was limited. The top three most common weeds in rights-of-ways were 1) *Bromus tectorum*; and 2) a tie between *Bassia scoparia* and *Cirsium arvense* while the most troublesome weeds were 1) *Bassia scoparia*; and 2) *Bromus* spp.*;* and a tie between *Salsola tragus* and *Sorghum halepense*. The 2021 weed survey data is available at: www.wssa.net/wssa/weed/surveys/.

Observed and Potential Future Impacts of Climate Change on the Midwest. Jim Angel*; Illinois water survey/University of Illinois, Champaign, IL (182)

Like the rest of the world, the Midwest has experienced human-induced climate change in recent decades. Observed changes in the Midwest include overall warming of 2°F over the last century with the strongest warming in winter and spring as well as at night. Precipitation has increased by 10-15 percent over the last century. Of special concern has been the increased frequency of extreme rainfall that produces more flooding, soil erosion, and nutrient loss in fields. Milder winters, longer growing seasons, and increased humidity add to the difficulties of managing pests and invasive species. Climate projections for the Midwest indicate that average temperatures could increase by 3 to 5°F by mid-century and 4 to 9°F by late century, depending on the scenario. Precipitation will continue to increase by the mid to late century. High confidence is placed on the increased risk of heatwaves and more extreme rainfall. Findings from the 2108 National Climate Assessment and more recent research will be presented.

Crops and a Changing Climate: Lessons Learned from FACE Experiments. Chris Montes*; USDA-ARS, Urbana, IL (183)

The effects of climate change are already being felt throughout Midwest agricultural systems. In the future, climate is likely to become increasingly variable and extreme. Different factors of climate change will be discussed taking a broad overview of what changes we can expect in the context of crop physiology. Potential positive, negative, and unknown effects of increasing concentrations of carbon dioxide and ozone, elevated temperature, changes in precipitation patterns, and the ultimate interactions of these factors on crop species will be highlighted through specific research conducted by a team of USDA-ARS and University of Illinois researchers at the Soybean Free Air Concentration Enrichment (SoyFACE) Facility located at the University of Illinois' Urbana campus. While the research conducted at SoyFACE predominately focuses on how factors of climate change affect soybean and corn, many of the general trends observed for C_3 and C_4 plants under future climate scenarios are likely applicable to weed species. The adaptive strategies evolved by many weed species to cope with drought and heat stress may be reinforced by some of the positive aspects of a changing climate making them even more competitive within our production systems. While the stresses of climate change placed on agriculture are demanding, we are presented with the opportunity to take advantage of the knowledge gained at facilities like SoyFACE to begin building resilience into our major agriculture species.

Carbon Dioxide, Climate and Competition: A New Paradigm. Lewis Ziska*; Columbia University, New York, NY (184)

Carbon Dioxide and climate change will have essential impacts on plant biology. At present there is strong evidence that weeds, particularly wild relatives of known crop species, are likely to respond to a greater extent with respect to growth and fecundity relative to their domesticated cousins. I will review data relative to both recent and projected increases in CO2 and climate change focusing on rice and soybean systems. I will also discuss opportunities to exploit these differences as a means of maintaining crop production with future CO2 and climate scenarios.

A Medley of Mechanisms: How Weeds Readily Adapt to a Changing Climate. David R. Clements*; Trinity Western University, Langley, BC, Canada (185)

Mechanisms by which weeds may readily adapt to a changing climate may be divided into four major categories: 1) specific genetic mechanisms, 2) plasticity, 3) innate weed persistence strategies, and 4) advantages due to the nature of human-weed relationships. Specific genetic mechanisms include hybridization, polyploidy, rapid evolution in invasion edges, and jettisoning of genetic load. Plasticity reflects the possession of an all-purpose genotype, thus pre-disposed to respond to variation in climate, although plasticity itself varies among weed species. Having innate persistence strategies, weeds are well-adapted to persist even apart from anthropogenic influences, and therefore able to respond to climate change more favorably than other plant species. However, putting such a tendency together with our human tendency to "create weeds" through our practices of crop management and other anthropogenic disturbances, the propensity for weeds to not only survive but thrive under climate change is greatly magnified. Thus, there is a medley of mechanisms that work together to create a crescendo of impacts as the average global temperature increases and extreme climate events multiply. I will discuss these four major categories of mechanisms through providing examples of weeds which are capable of, and to some extent already employ a plurality of these mechanisms to adapt to climate change, including knotweed (*Reynoutria* spp.), Himalayan balsam (*Impatiens glandulifera*), mile-a-minute (*Mikania micrantha*), parthenium weed (*Parthenium hysterophorus*), Johnsongrass (*Sorghum halepense*), kochia (*Bassia scoparia*), musk thistle (*Carduus nutans*), yellow starthistle (*Centaurea solstitialis*), common reed (*Phragmites australis*), Canada goldenrod (*Solidago canadensis*), common ragweed (*Ambrosia artemisiifolia*), cheatgrass (*Bromus tectorum*), ventenata (*Ventenata dubia*), wild oats (*Avena fatua*) and others. Given the broad array of weeds, coupled with a broad array of mechanisms for adapting and spreading, global climate change will inevitably usher in a planet of weeds unless we recognize how our recipe for creating weeds works that much better in the climate change oven, and try to disrupt the process. In other words, we need to recognize we are stringing together a medley in tune with the weeds and need to sing a new song, or at least a new adaptation that gives stronger voice to the other members of the choir.

Precipitation Extremes Influence Weed-Crop Interactions. Erin E. Burns*; Michigan State University, East Lansing, MI (186)

Nearly all crop production is impacted by precipitation patterns. Future climate scenarios for the Great Lakes Region predict more precipitation in heavy rainfall events, leaving more days during the growing season that have little or no precipitation, polarizing the wet and dry periods. To address this future climate scenario a field study was conducted in East Lansing, MI in 2018-2020 evaluating the impacts of reduced precipitation and weed competition on drought and non-drought tolerant corn hybrid performance and weed community composition. The study followed a completely randomized design with four replications. Factorial combinations consisted of hybrid (drought tolerant, DT or drought sensitive, DS), weed pressure (weed free, 50%, or no control), and precipitation (ambient or 70% reduced). Corn growth and development was measured at four growth stages. Weed species density was measured three times and biomass collected. At harvest, corn ears were harvested for yield component analysis. Data were analyzed in R using linear mixed effects, diversity indexes, and non-linear regression models. Weed density was not modified by corn hybrid. However, in July weed density was lower under reduced than ambient precipitation ($p = 0.001$). Furthermore, weed communities under reduced precipitation were more diverse in July than weed communities under ambient precipitation ($p = 0.02$). Species evenness was more uniform under reduced precipitation in July ($p = 0.009$). There was a significant main effect of weed pressure ($p < 0.0001$) and precipitation ($p = 0.007$) on corn yield. Averaged across weed pressures and precipitation, corn yield was not different between DT and DS hybrids ($p = 0.893$). Overall, corn yield was reduced by 31% under 100% weed competition compared to weed free or 50%. Results demonstrate that reduced precipitation and increasing weed pressure decreases corn yield and impacts species diversity and evenness. To further explore these relationships greenhouse experiments were conducted to evaluate water stress and weed competition on DT corn performance. The study followed a completely randomized design with four replications. Factorial combinations consisted of DT corn competition (presence or absence), water stress (100 or 50% volumetric water content (VWC)), and nine corn:common lambsquarters (*Chenopodium album* L.) densities. Corn and common lambsquarters growth parameters were measured 14 and 21 days after water stress initiation. To address the impact of reduced soil moisture and weed competition on corn and common lambsquarters growth parameters, photosynthetic response, and biomass; linear mixed effects and non-linear regression models were constructed in R. Overall, water stress and common lambsquarters competition negatively affected the parameters measured in this study; however, the magnitude of reduction is stronger under drought stress than increasing weed competition when water is not limiting. Ultimately, taking proactive integrated weed management steps by identifying the corn-weed competition principles investigated in these studies will allow field crop growers across the Great Lakes Region to integrate weed biology and crop physiology in the development of integrated economically viable weed management programs under future climate stress.

Climate Change Exacerbates the Damage of Weeds Through Reduced Herbicide Efficacy.
Maor Matzrafi*; Agricultural Research Organization- Volcani Institute, Ramat-yishay, IN (187)

Weeds cause significant crop yield and economic losses in agriculture. Treatment with herbicides is the most effective means of controlling weeds. Herbicide efficacy is strongly associated with environmental conditions. In recent years, we have witnessed an increase in both extreme weather events and reports on reduced herbicide sensitivity under unfavorable environmental conditions. This may emphasize the importance of maintaining proper environmental conditions at, but more importantly after herbicide application. This phenomenon is defined as conditional resistance - reduction in herbicide sensitivity under changed environmental conditions. In general, high temperatures and elevated CO_2 levels were shown to reduce herbicide efficacy, however, herbicide response in different environment conditions seems to be dependent on the active ingredient and on tested species or biotypes (R/S). It is proposed that the same mechanisms leading to non-target site resistance in weeds may also play a role in conditional resistance, suggesting we may be able to predict the herbicides to which weeds are likely to be less responsive under changing climatic conditions. Using adjuvants to improve herbicide translocation or reduce metabolism, alongside with new technologies such as using nanoparticles may result in higher functionality under the projected climate change.

Insights into How Warming Temperatures Can Reduce Herbicide Efficacy and Pose a Challenge for Weed Control. Mithila Jugulam*; Kansas State University, Manhattan, KS (188)

Changes in global climate factors, including temperature and CO_2 levels can influence agricultural practices including weed control. Invasive plants and weeds can out-perform crops under elevated temperature and CO_2 levels. Temperature is also one of the important factors that can impact postemergence herbicide efficacy, thereby, weed control. Currently, the evolution of herbicide resistance in weeds poses an increased challenge for weed management across the US. Temperature fluctuation can also alter the level of resistance to herbicides in weeds, and hence, their management. In our lab, we investigated the effect of temperature stress on efficacy and resistance level of mesotrione, glyphosate, dicamba, and 2,4-D in important weeds of Midwestern agriculture, such as common waterhemp, Palmer amaranth, kochia, giant or common ragweed, and lambsquarters. Our data suggest that warmer temperatures (34/ 20 °C d/n) reduce the control of both 2,4-D-resistant and susceptible common waterhemp, primarily because of the rapid metabolism of 2,4-D at high-temperature stress. Similarly, Palmer amaranth was more sensitive to mesotrione at low (25/15 °C d/n) than high temperatures (40/30 °C d/n), yet again, because of the rapid metabolism of this herbicide at high temperature. Also, at high temperatures, poor control of kochia when treated with dicamba was found, because of reduced translocation of this herbicide. On the other hand, reduced absorption of glyphosate was found to contribute to poor control of kochia at high temperatures. Improved control of common lambsquarters with glyphosate was found when plants were grown at cooler conditions (25/15 °C d/n). In contrast, improved efficacy of 2,4-D or glyphosate occurred at high temperatures (29/17 °C d/n) than low temperatures (20/ 11 °C d/n) regardless of susceptibility or resistance of this weed species to these herbicides. Overall, improve herbicide efficacy and weed (resistant or susceptible) control were found when herbicides are applied at cooler than warmer temperature conditions. These findings imply that future changes in climatic conditions may affect herbicide performance and potentially increase the incidence of herbicide-resistant biotypes.

The Effects of a Changing Climate on Weed Populations and Herbicide Resistance Evolution. Eric L. Patterson*; Michigan State University, East Lansing, MI (189)

Climate forecasts for the coming years predict increases in global temperature, carbon dioxide concentration, and extreme weather events. These changes will continue to impact agricultural production by altering the stress landscape imposed on plants, including both crops and weeds. Furthermore, it will influence their relative fitness when they are in direct competition, usually in favor of the weed species. One of the critical factors that will determine the ability of a species to withstand the drastic impacts of climate change is the species inherently standing diversity, its ability to generate novel diversity, and its overall genetic toolkit. Most weeds are prolific out-crossers with an abundance of genetic diversity and complex genomes. For these reasons (among others) it is predicted that weeds will continue to adapt to the changing climate more rapidly than the crops they compete with. As an example, I will focus my talk on the predicted impacts of climate change on the population structure of *Kochia scoparia*. Kochia, one of the most common weeds in North America, is a C4 plant exceptional for its drought tolerance. Kochia has also demonstrated rapid adaption and evolution to the abiotic stress of herbicide application, particularly glyphosate. Abiotic stresses from both climate change and herbicides impact the distribution and expansion of kochia. Being aware of the features and properties of kochia, especially those resulting from herbicide resistance, will help anticipate how kochia responds or migrates under future climate change, and help create proper strategies for kochia weed management.

Climate Change Influences on Pest Treatment Costs and Strategies. Bruce McCarl*; Texas A&M University, College Station, TX (190)

One possible effect of climate change involves whether crop damages from pests will increase or shift. As climate change can alter pest populations, migration behavior and spatial incidence, farmers may face altered needs for and cost of pest management. We examine how the current climate affects the distribution of pesticide costs. We do this for five crops: corn, potato, soybean, spring wheat and winter wheat. We construct interrelationships between pesticide cost and climate for herbicides, insecticides, and fungicides along with total pesticide cost. Empirically we find that increases in precipitation increases average per acre total pesticide cost for soybean, spring wheat and winter wheat, but decreases the cost for corn and potato. Meanwhile, total pesticide cost decreases as average temperature rises for potato, soybeans and winter wheat, but increases the cost for corn and spring wheat. Moreover, extreme climate events such as drought show an inverted U-shaped effect on pesticide cost for all five crops, indicating that pesticide expenditure rises as the frequency and magnitude of drought increases past a critical level.

Climate and Herbicide Interaction Project: Using Past Data to Predict Future Consequences. Christopher A. Landau*; University of Illinois, Urbana, IL (191)

Current climate change predictions of global grain yields do not account for the fact that weeds are widespread in crop production, weather variability influences performance of weed management tactics, and due to growing prevalence of herbicide resistance, weeds are becoming more difficult to control even in regions producing the most grain. Empirical research on climate change and weeds is limited to either controlled environment studies limited to a few independent variables of interest, or field trials totaling only a handful of site-years. Capturing weed and crop management outcomes in the full range of environmental conditions is difficult where weather variability is high, such as the U.S. Corn Belt. Our team is framing new questions and exploiting historical herbicide evaluation datasets to extract new knowledge about weed management and weather variability. To date using University of Illinois (UIUC) data, we have found 1) future efficacy of important preemergence herbicides in corn is threatened by more variable weather expected in the coming decades and 2) diminishing weed control exacerbates corn and soybean yield loss to adverse weather; a cautionary note for those predicting future yields. Datasets equivalent to UIUC's exist in the U.S. and using them would greatly expand the inference space (e.g., more soils, weather, weed species, etc.) of the research. We have built a collaborative network among some 20 university extension weed scientists located throughout the U.S. to further exploit the untapped potential of such historic datasets. In the short term, data are being compiled into a single database. Various data analyses and machine learning techniques then will be employed to extract new knowledge and generate forward-looking hypotheses, which will serve as the basis for future research. As weather patterns continue to become more volatile and extreme, understanding the risks that climate change poses to efficacy of existing and new weed management systems will be valuable as agriculture adapts to a changing climate.

Yoga and Perspectives on a Successful Career in Industry. Mark Peterson*; Affiliation Not Specified, West Lafayette, IN (192)

NO ABSTRACT SUBMITTED. Abstracts were not requested for symposia and were submitted on a voluntary basis.

I Didn't Want to Go to College; Now I Don't Want to Leave. Patrick Tranel*; University of Illinois, Urbana, IL (193)

NO ABSTRACT SUBMITTED. Abstracts were not requested for symposia and were submitted on a voluntary basis.

What's Behind Door Number 3: What My Major Prof Didn't Tell Me. Eric P. Spandl*; Winfield United, River Falls, WI (194)

NO ABSTRACT SUBMITTED. Abstracts were not requested for symposia and were submitted on a voluntary basis.

Panel Discussion: Career Paths. Ednaldo A. Borgato*; Kansas State University, Manhattan, KS (195)

NO ABSTRACT SUBMITTED. Abstracts were not requested for symposia and were submitted on a voluntary basis.

Industry Resumes: Finding Way to Top of the Stack. Stott Howard*[1], Dawn Refsell[2];
[1]Syngenta Crop Protection, Des Moines, IA, [2]Valent USA LLC, Lathrop, MO (196)

NO ABSTRACT SUBMITTED. Abstracts were not requested for symposia and were submitted on a voluntary basis.

Preparation and Execution: the Difference in Nailing or Failing That Industry Interview.
David M. Simpson*; Corteva Agriscience, Indianapolis, IN (197)

NO ABSTRACT SUBMITTED. Abstracts were not requested for symposia and were submitted on a voluntary basis.

Interview Preparation for an Academia Career. Harlene M. Hatterman-Valenti*; North Dakota State University, Fargo, ND (198)

NO ABSTRACT SUBMITTED. Abstracts were not requested for symposia and were submitted on a voluntary basis.

About That Job Interview. Stott Howard*; Syngenta Crop Protection, Des Moines, IA (199)

NO ABSTRACT SUBMITTED. Abstracts were not requested for symposia and were submitted on a voluntary basis.

Panel Discussion. Dawn Refsell*[1], Stott Howard[2], Erin E. Burns[3], Ednaldo A. Borgato[4]; [1]Valent USA LLC, Lathrop, MO, [2]Syngenta Crop Protection, Des Moines, IA, [3]Michigan State University, East Lansing, MI, [4]Kansas State University, Manhattan, KS (200)

NO ABSTRACT SUBMITTED. Abstracts were not requested for symposia and were submitted on a voluntary basis.