‘Unofficial’ NCWSS 2020 Proceedings

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Quantitative Expression Analysis of Homoeologous Wheat CYP81A-like Genes Following Single and Combined Halauxifen-methyl and Cloquintocet-mexyl Foliar Treatments. Olivia A. Obenland*, Brendan V. Jamison, Kris N. Lambert, Dean E. Riechers; University of Illinois, Urbana, IL (1)

In both crop and weed species, members of the CYP81A family of cytochrome P450s (P450s) are associated with metabolism of several herbicides, including synthetic auxin herbicides. While this P450 protein family has been examined in several grass species, research regarding this P450 family is lacking for *Triticum aestivum* (cultivated bread wheat), an allohexaploid species. Three CYP81A-like P450s located on the group 5 chromosomes (denoted as *CYP5A*, *CYP5B*, and *CYP5D*) of wheat were previously identified by an RNA-Seq experiment that measured differential transcript expression between untreated wheat leaf tissue and tissue treated with the herbicide safener, cloquintocet-mexyl (CM). Halauxifen-methyl (HM) is a synthetic auxin herbicide commonly utilized with CM in a tank mix in order to reduce wheat injury. We hypothesized that one or more of these group 5 P450s encode HM-detoxifying P450s that govern natural or safener-inducible wheat tolerance to HM. As a result, the objective of this research was to utilize RT-qPCR with homoeolog-specific primers and probes to measure expression of *CYP5A*, *CYP5B*, and *CYP5D* in wheat leaf tissue treated with foliar applications of CM, HM and the combination of CM + HM relative to an untreated control tissue at three time points. Wheat seedlings with 1-2 leaves (Zadoks stages 11-12) were treated CM, HM, or CM+HM, and leaf tissue was collected at 3, 6, and 12 hours after treatment (HAT). At each time point these genes were only significantly induced by CM and CM+HM, and these inductions were significantly higher than responses to HM alone. However, significant inductions in response to CM and CM+HM treatments were not significantly different from each other. Significant inductions for all three P450 genes were only observed at 3 HAT, and the *CYP5D* gene consistently had higher fold inductions than its homoeologs, *CYP5A* and *CYP5B*, across all time points tested. Overall, our results demonstrate these CYP81A-like genes are CM inducible but not HM inducible, and additive or synergistic fold-inductions between HM and CM were not detected. Further experimentation, such as gene knock-out or overexpression experiments, is necessary to test the hypothesis that the encoded P450(s) detoxify HM and if CM enhances this detoxification process.

The Genetics of Multiple Glyphosate Resistant Kochia Plants from Colorado Sugarbeet Fields. Philip Westra*[1], Andrew Effertz[2], Todd A. Gaines[1], Crystal D. Sparks[1], Sarah Moran[1]; [1]Colorado State University, Fort Collins, CO, [2]Colorado State University, Ft Collins, CO (2)

NO ABSTRACT AVAILABLE

Effect of Degree of Water Stress on Growth and Fecundity of Velvetleaf (*Abutilon theophrasti*) Using Soil Moisture Sensors. Jasmine M. Mausbach*[1], Suat Irmak[1], Parminder S. Chahal[2], Debalin Sarangi[3], John Lindquist[1], Amit J. Jhala[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]FMC Corporation, Lincoln, NE, [3]University of Minnesota, St. Paul, MN (3)

Velvetleaf (*Abutilon theophrasti*) is a troublesome weed, causing severe crop losses due to competition for resources like water. The objective of this study was to determine the effect of degree of water stress on the growth and fecundity of velvetleaf using soil moisture sensors under greenhouse conditions. Velvetleaf were grown in loam soil maintained at 100%, 75%, 50%, and 25% soil field capacity (FC) corresponding to no, light, moderate, and high water stress conditions, respectively. Water was regularly added to pots based on soil moisture levels detected by Decagon 5TM sensors to maintain the desired water stress level. Velvetleaf plants maintained at 25% FC did not survive more than 49 d after transplanting. Velvetleaf at 100% and 75% FC produced similar numbers of leaves based on model estimates; however, plants at 50% FC produced a significantly lower number of leaves. Plants at 75% FC achieved the maximum height compared with 100% and 50% FC, respectively. The growth index of velvetleaf was significantly different across water stress levels. Plants maintained at 75% FC had the highest growth index compared with the growth indexes at 100% and 50% FC. The time it took for 50% FC to reach 50% of the maximum growth index achieved by 75% FC was significantly longer than 100% FC. The results of this study show that velvetleaf can survive =50% FC continuous water stress conditions, although with significantly reduced leaf number, plant height, and growth index.

Transcriptomics-based Identification of Candidate Genes Responsible for Reduced Dicamba Sensitivity in Waterhemp (*Amaranthus tuberculatus*). Lucas K. Bobadilla*[1], Patrick Tranel[2]; [1]University of Illinois, Champaign, IL, [2]University of Illinois, Urbana, IL (4)

Waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer) is one of the most troublesome weeds in the Midwest, and it is known for its rapid herbicide-resistance evolution. In 2012, a waterhemp population (CHR) was identified in Champaign County, Illinois, USA, after unsuccessful HPPD inhibitor herbicide control. Since then, the CHR population was identified to be resistant to multiple herbicides, including inhibitors of ALS, PPO, Photosystem II, and HPPD, and 2,4-D. During field and greenhouse trials, some CHR plants were identified to survive 560 g ae ha^{-1} of dicamba. Dose responses and segregation analyses were conducted to characterize inheritance. Those experiments showed a resistance index of 9 to 10 between resistance and sensitive plants and characterized the dicamba resistance trait as a multi-genic and incompletely dominant trait with a heritability of 0.71. This study's objective was to conduct an RNA-seq experiment to identify potential candidate genes involved with dicamba resistance and identify if dicamba resistance is cross-resistance due to 2,4-D resistance. Sixteen pseudo-F2 plants were selected for sequencing, from which eight were resistant and eight sensitive to dicamba. Plant tissues were collected before dicamba application to reduce unrelated noise with the trait of interest. A NovaSeq 6000 system with a flow cell SP-100bp was used to sequencing all the 16 RNA libraries delivering an average of 65 million reads per sample. RNA-seq pipeline analysis consisted of trimming adapters and filtering low quality reads using Trimmomatic and SortMeRNA, mapping reads to the waterhemp genome using STAR, genome-guided de novo transcriptome assembly using Trinity, transcriptome annotation using Trinotate, and pseudo-mapping abundance estimation with Kallisto. Differential expression analysis was conducted at the gene-level using the EdgeR package, and transcript-level analysis using the Sleuth package in R. Variant calling was done using the GATK pipeline and alternative splicing analysis using DEXseq. Primers were designed and tested for efficiency, and a real-time qPCR was used to validate selected genes. Differential expression analysis at the gene-level identified 103 differentially expressed genes between resistant and sensitive plants, while at the transcript-level, 22 transcripts were differentially expressed. The identified genes were further filtered based on GO-terms and KEGG ontology, yielding four potential candidate genes. Candidate gene products are involved in the early response to auxins, auxin efflux transport, auxin catabolism, reactive oxygen species (ROS) detoxification, and ethylene/abscisic acid regulation. No significant structural variants (e.g., SNPs) were identified, and one of the candidates shows a putative alternative splicing event. qPCR validation confirmed the differential expression of three candidate genes identified from RNA-seq. None of the identified candidates were identified from previous RNA-seq analysis for 2,4-D resistance in the CHR population, indicating that dicamba resistance is potentially a distinct resistance mechanism. Future studies will include primers' design to confirm the remaining candidate gene, testing via qPCR of other pseudo-F2 plants for relative expression of the candidate genes, and investigating the expression patterns after dicamba application.

Metabolite Profiling of Waterhemp (*Amaranthus tuberculatus*) Populations Reveals the Resistance Mechanism to a Non-selective HPPD-inhibiting Herbicide. Jeanaflor Crystal T. Concepcion*[1], Shiv S. Kaundun[2], Sarah-Jane Hutchings[2], James A. Morris[2], Anatoli V. Lygin[1], Dean E. Riechers[1]; [1]University of Illinois, Urbana, IL, [2]Syngenta Crop Protection, Bracknell, United Kingdom (5)

Metabolic resistance to herbicides that inhibit 4-hydroxyphenylpyruvate dioxygenase (HPPD, EC 1.13.11.27) is increasingly becoming more challenging, particularly among populations of waterhemp (*Amaranthus tuberculatus*) that are widespread in the Midwestern USA. Previous studies using commercial HPPD-inhibiting herbicides have demonstrated that rapid oxidative metabolism of the parent compound confers resistance in multiple herbicide-resistant (MHR) waterhemp populations and tolerant corn. Considering the mechanisms of resistance in MHR to these commercial herbicides and the possibilities of finding novel resistance mechanisms, our current research aims to identify the resistance mechanism of MHR to a non-selective and presumably metabolically blocked HPPD-inhibiting herbicide, called syncarpic acid-3 (SA3), using metabolite profiling (metabolomics). Untargeted metabolomics was utilized in order to capture as many metabolites as possible, find trends in the global metabolite variation between the waterhemp populations and to compensate for the lack of analytical standards for putative SA3-metabolites and the unavailability of existing literature for this herbicide. Recent advances in separation techniques, most notably liquid chromatography (LC), combined with mass spectrometry (MS), have enabled the detection of a wide range of primary and secondary metabolites in complex sample matrices such as plant extracts. Metabolite profiling was carried on two independent experiments consisting of two waterhemp populations: Stanford Illinois Resistant (SIR) and Adams County HPPD-inhibitor-sensitive but atrazine-resistant (ACR). The first experiment used an excised leaf assay that consisted of three biological replicates for each SIR and ACR population at 4 and 12 hours. The second experiment used whole plants and carried out on SIR and ACR at three time points (12, 24 and 48 hrs). Both experiments included experimental blanks and pooled samples as part of the experimental quality assurance and quality control procedures. Analyses of plant extracts using LCMS in both positive and negative electrospray ionization were performed on a HPLC system coupled to a Q Exactive Hybrid Quadrupole-Orbitrap Mass Spectrometer. Data pre-processing was conducted using Compound Discoverer and MS-Dial software followed by multivariate statistical analyses via principal components analysis (PCA) using Umetrics SIMCA v15. In both experiments, more than 2000 compounds were detected. Although some of the metabolites were putatively identified using online databases, the majority of the compounds were unknowns. PCA showed clear separation between the two populations and between the time points after treatment. Several polar and semi-polar metabolites were characterizing for SIR and their mass spectral information reveal a putative lack of metabolism on the aryl ring of SA3. Using untargeted metabolomics, we demonstrated that SIR metabolizes SA3 at a much faster rate than ACR as evidenced by the increased abundance of several polar, semi-polar and higher molecular weight compounds derived from SA3 in SIR. Future research will characterize these polar and semi-polar metabolites formed in SA3-treated samples using their mass spectral information, and deduce the possible metabolic enzymes involved in SA3 detoxification reactions in SIR via enzyme activity assays and proteomic techniques.

QTLs For HPPD-inhibitor Resistance in a Nebraska *Amaranthus tuberculatus* Population.
Brent P. Murphy*, Patrick Tranel; University of Illinois, Urbana, IL (6)

Herbicide resistance within waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer) is a major issue for weed management with the American Midwest. Herbicide resistance within this species has been reported to seven sites of action, including hydroxyphenylpyruvate dioxygenase (HPPD), and including numerous cases of multiple-resistant populations. The genetic architecture of non-target-site herbicide resistance is often poorly understood. With the recent release of several high quality genomes for waterhemp, QTL mapping has become a viable strategy for the characterization of resistant populations. An HPPD-inhibitor resistant waterhemp population from Nebraska, from a site with no field use history of HPPD chemistries, was characterized at the phenotypic and genotypic levels. Resistance ratios of 15 and 21 were observed within the parental and F_1 generation in response to tembotrione. Segregation within the pseudo-F_2 generation suggested HPPD-inhibitor resistance was a complex trait with moderate heritability (H=0.556) in this population. Bulk-segregant analysis identified five putative QTL, and subsequent validation through population-specific molecular markers confirmed that two of these QTL, on Scaffold 4 and Scaffold 12, were associated with HPPD-inhibitor resistance. QTL mapping is a powerful approach to characterize complex traits for herbicide resistance, and the generation of molecular markers within each QTL will allow for the isolation of causal resistance factors for physiological characterization and functional validation.

Indaziflam resistance in *Poa annua*. L.Jinyi Chen [1], James Brosnan [2], Eric Patterson[1]; [1]Michigan State University, Department of Plant, Soil, and Microbial Sciences, [2]University of Tennessee, Department of Plant Sciences (7)

Indaziflam is a cellulose-biosynthase inhibiting herbicide used to control annual bluegrass (*Poa annua* L.). Several locations in the southeastern USA reported poor annual bluegrass management following treatment with indaziflam during autumn 2015. A series of controlled environment experiments were conducted to confirm putative resistance to indaziflam in annual bluegrass collected from these field locations. When indaziflam (25 g ha^{-1}) was applied early-postemergence (< 2.5 cm plant height), three populations were exhibiting high survival rate. In agar-based plate assays, early-postemergence I50 values for these putative-resistant collections ranged from 2424 to 4305 pM, compared with 633 pM for the herbicide-susceptible control; therefore, resistance indexes (R/S) ranged from 3.8 to 6.8. We confirm that these annual bluegrass collections are resistant to early post-emergence indaziflam application, and agar test can be used as a quick method for indaziflam resistance detection. Additional research to better understand resistance mechanisms in these annual bluegrass collections is warranted.

Mechanism of Lactofen Resistance in Palmer Amaranth from Kansas. Ednaldo A. Borgato*, Balaji Aravindhan Pandian, Sathishraj Rajendran, Anita Dille, Mithila Jugulam; Kansas State University, Manhattan, KS (8)

Target- and non-target site-based resistance to protoporphyrinogen IX oxidase (PPO)-inhibitors has been reported in many populations of Palmer amaranth across the US. A Palmer amaranth population (KCTR) found in a research field near Manhattan, KS, showed lack of control with several commonly used herbicides. This population specifically survived (84%) lactofen application (219 g ha^{-1}). The objectives of this research were to confirm and to characterize resistance to lactofen in KCTR Palmer amaranth. KCTR plants were screened with lactofen at 219 g ha^{-1} and survivors were allowed to mate producing KCTR(G2) offspring. Dose-response studies were performed in greenhouse conditions with KCTR, KCTR(G2) and a susceptible population from Kansas (KSS) or Mississippi (MSS), with doses ranging from 0 to 438 for susceptible and from 0 to 7008 g ha^{-1} for resistant Palmer amaranth, with at least ten replicates (1 plant per pot) and repeated. To identify whether the *PPX2* is involved in resistance in KCTR, sequences and expression levels from KCTR were compared to KSS. To assess the involvement of metabolism-based resistance mediated via cytochrome P450 or glutathione *S*-transferase (GST) activity, greenhouse assays were performed with applications of lactofen in combinations with and without a P450- and GST-inhibitor. Dose-response analysis confirmed resistance to lactofen in KCTR. *PPX2* sequence alignment revealed absence of previously reported mutations conferring resistance to PPO-inhibitors in Palmer amaranth. Additionally, gene expression assays revealed no difference in expression of the *PPX2*. Interestingly, the addition of the P450-inhibitor (malathion) restored sensitivity in KCTR. These results suggest that P450 enzyme-mediated metabolism of lactofen confers resistance to this herbicide in KCTR rather than any alterations in the *PPX2*. Research is in progress to identify the lactofen-metabolites, and also understand the genetic basis of resistance to PPO-inhibitors in KCTR Palmer amaranth.

Evaluation of Italian Ryegrass (*Lolium perenne spp. multiflorum*) Seed Retention and Distribution in Wheat at Harvest. Amber L. Herman*, Travis Legleiter; University of Kentucky, Princeton, KY (9)

There is a growing concern over herbicide resistance in Italian ryegrass (*Lolium perenne spp. multiflorum)* in the state of Kentucky and new ways to control this weed in wheat are needed. One possible method of control is the use of a harvest weed seed destructor at wheat harvest to destroy *L. multiflorum* seed that is in the fine chaff portion of the harvest chaff. The *L. multiflorum* seed would have to be retained on the plant until wheat harvest for a harvest weed seed destructor to be effective. The seed retention and distribution of Italian ryegrass prior to wheat harvest and at the time of harvest were studied in Kentucky during the summer of 2020. Prior to harvest wheat heads, *L. multiflorum* seed heads, and the top layer of the soil debris was collected from within a m^2 area for each half acre *L. multiflorum* infestation in two Kentucky wheat fields. The wheat seed heads were collected for grain moisture analysis of the field. *L. multiflorum* seed heads and ground debris samples were cleaned and analyzed for total *L. multiflorum* seed each. At wheat harvest four 0.4 ha plots were established in a *L. multiflorum* infested wheat field in Princeton, KY. Combine head shatter losses and chaff were collected in four $1m^2$ areas within each 0.2 ha plot. A grain tank sample was also collected at the end of each plot. Samples were cleaned and analyzed for *L. multiflorum* seed counts per $1m^2$. The results from the pre harvest collections showed that a majority of the seed was retained on the seed head with approximately 11,000 *L. multiflorum* seeds/m^2 retained on the seed heads at both the Young Road and UKREC fields. In comparison, approximately 2500 and 4000 *L. multiflorum* seed/m^2 were found to within the ground samples for the Young Road and UKREC fields, respectively. The at harvest study revealed that 7000 *L. multiflorum* seeds/m^2 were contained in the combine chaff and was significantly greater than the proportion of seeds shattered at the combine head at 4500 *L. multiflorum* seeds/m^2. Grain tank sample analysis revealed that 5000 *L. multiflorum* seeds/m^2 were contained in the grain tank and was equivalent to both the chaff and head shatter proportions. Overall results of this study show that *L. multiflorum* seed is primarily retained on the seed head up to wheat harvest and that the majority of *L. multiflorum* seeds are contained in the combine chaff at harvest. These results indicate that the harvest weed seed control is possibly a viable *L. multiflorum* control option in Kentucky wheat.

Comparative Growth of Palmer Amaranth (*Amaranthus palmeri*) and Waterhemp (*A. tuberculatus*) in Iowa. Rebecca S. Baker*[1], Bob Hartzler[2]; [1]Iowa State University, Ames, IA, [2]Iowa State, Ames, IA (10)

Waterhemp (*Amaranthus tuberculatus [Moq.] J.D. Sauer*) is a weedy species, native to the Midwestern United States that has become resistant to herbicides. The emergence and growth of waterhemp have been studied extensively in Iowa. Palmer amaranth (*A. palmeri S. Watson*) is a relative of waterhemp, but it is native to the southwestern United States. It has also evolved resistance to several herbicides and has moved northward in the United States, where it was recently introduced in Iowa. The management of both species is complicated by prolonged emergence patterns and seed persistence. Palmer amaranth is a large plant, producing large amounts of seed and biomass. Waterhemp is comparatively smaller, but still highly fecund. Studies were done to compare the growth and reproductive abilities of waterhemp and two biotypes of Palmer amaranth in Iowa. Emergence patterns of waterhemp collected in Iowa (WH), Palmer amaranth collected in Iowa (IA), and Palmer amaranth collected in Kansas (KS) were studied by counting seedlings emerged from an artificial seedbank. Seed persistence of WH, IA, and KS were compared when the seeds were buried at the soil surface and 15 cm depth. A common garden study compared the growth, biomass, and seed production of WH, IA, and KS under non-competitive conditions. On average, 50% of all waterhemp emergence occurred before May 31, about two weeks earlier than Palmer amaranth, but all three varieties emerged throughout the growing season. Viability of seeds buried at the soil surface varied between populations, but all had >50% of seed remaining after a year of burial at 15 cm. Palmer amaranth produced taller plants with up to 80% greater biomass than waterhemp, but seed production was similar between species and biotypes. Prolonged emergence and seed persistence will complicate management of Palmer amaranth in Iowa, but similarities to waterhemp suggest that management strategies could be similar for both species. Further research includes screening for herbicide resistant populations of Palmer amaranth in Iowa.

Evaluating Indiana Palmer Amaranth Populations for Resistance to Dicamba. Claudia R. Bland*; Purdue University, West Lafayette, IN (11)

Palmer amaranth (*Amaranthus palmeri)* has rapidly become one of the most problematic weeds in the Midwest and southern cropping systems. It's ability to evolve resistance to many postemergence herbicides poses a threat to the efficacy of the synthetic auxin herbicides used in tolerant soybean varieties. Previous research characterized tolerance of 41 Indiana Palmer amaranth populations to nine different herbicides, where dose response assays showed low levels of dicamba tolerance in five populations. In a subsequent greenhouse study, four populations showing low levels of tolerance to dicamba plus one sensitive population were selected and treated with foliar applications of six doses of dicamba (0, 29, 57, 114, 227, and 454 g ae ha^{-1}). Plants were propagated by scarification of seed with a 10% bleach solution, sown into 10x20cm flats containing potting mix, and transplanted into 10 cm^2 pots containing a 1:1 mixture of potting mix and field soil at the first true leaf stage. Herbicide applications were made at the 6- to 8- true leaf stage in 140 L/ha carrier volume. Visual control estimates were taken at 14- and 21- days after treatment (DAT) and aboveground biomass were taken at 21 DAT. Data were analyzed with non-linear regression using the drc package to detect differences in the population visual control estimates and biomass reductions. GR_{50} and GR_{90} values were calculated from dried biomass data. No differences were observed in the visual control estimates or biomass data, but trends were observed in survival of individual plants in selected populations following exposure to 114 and 227 g ae/ha. Population five showed the lowest levels of survival with 3 and 1 plant surviving, respectively. Populations two, three, and four had 6, 7, and 6 survivors, respectively, at the 114g rate and 5, 4, and 2 survivors at the 227g rate. Moreover, all populations, had one or more plants out of 8 survive the highest rate, 454g, except for the sensitive control population. This represents a 12.5% survival rate, which would be considered a failure in a field application. These trends show that all populations have problematic plants, even though they showed no differences in biomass or visual control estimates when averaged over the whole population. Further investigation will be needed in order to confirm this observed trend by propagating surviving plants and rescreening the progeny.

The Effects of Cereal Rye (*Secale cereale*) Seeding Rate and Termination Timing on Weed Control and Soybean Yield. Alyssa Essman*, Mark Loux, Alexander Lindsey, Anthony Dobbels; Ohio State University, Columbus, OH (12)

There has been increased interest in cover crops in recent years due in part to their potential for weed suppression, and their potential role in the integrated management of herbicide-resistant weeds. Growers have been experimenting with different methods of cover crop termination in an attempt to maximize their weed suppression and potentially reduce herbicide inputs. One of the most common cover crops used in these systems is cereal rye (*Secale cereale* L.). Cereal rye can be planted later in the fall than other species and produce a considerable amount of biomass, which makes it especially suitable for use after corn (*Zea mays* L.) and before soybean [*Glycine max* (L.) Merr.] in Ohio crop rotations. A field study was conducted twice from fall of 2018 through the fall of 2020 at the OARDC Western Agricultural Research Station in South Charleston, Ohio to evaluate different rye termination systems. The objectives of this research were to: (1) determine the effect of rye seeding rate on weed density and soybean yield; and (2) determine the effects of different termination timings and herbicide systems on weed density and soybean yield. The three factors in this study were: rye seeding rates - 0, 50, and 101 kg ha^{-1}; termination systems - 7 days before soybean planting, 7 days after soybean planting, and rye terminated 21 days after plant with an early April application of saflufenacil and termination as the only POST application; and level of spring residual herbicide - flumioxazin + chlorimuron ethyl, none. Measurements included rye biomass, density of summer annual weeds, and soybean density and yield. The density of giant foxtail (*Setaria faberi* Herrm.) was reduced at both rye seeding rates compared with no cover in year one. The presence of rye did not affect density of giant ragweed (*Ambrosia trifida* L.) in either year, compared with no cover. Terminating rye 21 days after soybean planting was associated with the lowest weed density, but was not always significantly different than rye terminated 7 days after soybean planting. Density of giant foxtail was lower in treatments with a residual herbicide both years, but level of residual herbicide did not have an effect on the density of giant ragweed. Terminating rye after planting resulted in increased soybean yield in year one, but yield was reduced at the 21 day after plant termination in year two. These results suggest that adjustments to termination timing may have more of an effect on weed suppression from a rye cover crop than adjustments to rye seeding rate. Spring-applied residual herbicides are still needed to provide adequate weed control into the growing season. Rye can be terminated after soybean planting to aid in the suppression of weeds without reducing soybean yield, although this likely varies with environmental conditions.

Inhibiting Herbicide-Resistant Amaranthus by Suppressing Reproduction. Efrat Lidor Nili*[1], Ido Shwartz[1], Herve Huet[1], Miriam Aminia[1], Yuval Kadan[1], Micheal D. Owen[2], Orly Noivirt-Brik[3]; [1]WeedOUT, Ness Ziona, Israel, [2]Affiliation Not Specified, Ames, IA, [3]WeedOUT Ltd., Ness Ziona, Israel (13)

Our new technology to help manage herbicide-resistant weeds is based on the inhibition of the natural reproduction system of weeds. Our method involves application of irradiated weed pollen onto escaped weeds in the field. The irradiated pollen outcompetes natural pollen, resulting in the formation of non-viable seeds, depleting the weed seedbank. Technically, weed pollen is harvested and then irradiated with a carefully determined dose of X-ray-radiation that does not kill the pollen but prevents normal seed development upon fertilization. Such pollen has been applied in the field, leading to a significant reduction in weed seedbank replenishment. Proof of concept of the technology was demonstrated using *Amaranthus palmeri* where newly formed seeds lost their ability to germinate. Following a successful field trial in a setting of a corn field infested with a uniform level of *A. palmeri* in Israel in 2018, it was tested in 2019 in Georgia, US. The US field trial tested the technology in a setting of a cotton field infested with a uniform level of *A. palmeri*. The trial examined the technology under two experimental setups: 1. Applying only irradiated pollen treatment, to evaluate the capabilities of the technology alone under several treatment regimens; 2. In a setting that mimics dicamba resistance and included a dicamba application in the beginning of the season (on ~7-10 inches *A. palmeri* seedlings) and applications of irradiated pollen in various regimens during late season. The best regimens in both settings demonstrated reduction of more than 40% in the number of newly formed seeds (48% in the irradiated pollen alone treatments with p-value <0.01 and 41% in the dicamba followed by irradiated pollen treatments with a p-value = 0.026). More field experiments are planned. This pollen-based strategy has the potential of providing a long-term solution to significantly manage weed resistance as a part of an integrated weed management approach. Moreover, since the technology is based on the fundamental process of reproduction, it is less prone to the rapid evolution of resistance to the technology.

Identifying and Quantifying Resistance to Soil-applied Herbicides in Waterhemp (*Amaranthus tuberculatus*) Populations from Illinois Using a Soilless Method. Dylan R. Kerr*[1], Seth A. Strom[2], Jeanaflor Crystal T. Concepcion[2], Dean E. Riechers[2]; [1]University of Illinois, Champaign, IL, [2]University of Illinois, Urbana, IL (14)

Previous research has demonstrated two multiple-resistant waterhemp (*Amaranthus tuberculatus*) populations (CHR and SIR) from Illinois displayed resistance to several Group 15 herbicides, notably *S*-metolachlor, in the field and greenhouse. Group 15 herbicide efficacy is affected by edaphic factors such as organic matter, pH, soil texture, and application timing and rainfall amount. The goal of this research was to limit and control edaphic effects on Group 15 herbicides by developing a soilless assay to characterize herbicide efficacy using two known Group 15 herbicide-resistant (CHR and SIR) and -sensitive (ACR and SEN) waterhemp populations. Dose-response experiments were conducted under greenhouse conditions with pre-germinated seeds from each waterhemp population. Pre-germinated seeds were planted on the surface of vermiculite saturated with *S*-metolachlor or pyroxasulfone solutions at concentrations ranging from 0.015–15 µM and 0.0005–5 µM, respectively, then lightly covered with dry, untreated vermiculite. Pots were sub-irrigated every second day using fresh hydroponic solution without herbicide for 14 days, then seedlings were counted, and above-ground biomass was harvested 14 days after herbicide treatment. Dose-response experiments using *S*-metolachlor and pyroxasulfone were conducted to calculate the effective dose causing a 50% reduction in survival (LD_{50}). LD_{50} values for *S*-metolachlor were 2.4 µM, 2.4 µM, 0.2 µM, 0.1 µM for CHR, SIR, ACR, and SEN, respectively. Values for pyroxasulfone were 0.1 µM, 0.09 µM, 0.02 µM, 0.03 µM for CHR, SIR, ACR, and SEN, respectively. Resistant-to-sensitive (R:S) ratios for *S*-metolachlor were also calculated, which were 18 and 17 for CHR and SIR, respectively. Resistant-to-sensitive ratios for pyroxasulfone were 5 and 3 for CHR and SIR, respectively. Results from these soilless assays are consistent with previous findings using soil-based systems and demonstrate that CHR and SIR are resistant to *S*-metolachlor and pyroxasulfone. As a result, this soilless method could provide a promising high-throughput alternative for studying preemergence herbicide efficacy on suspected resistant populations that can be conducted on a relatively small scale, which could be altered to meet the requirements of many types of dose-response or physiology experiments.

Termination Timing and Cover Crop Species Influence Weed Suppression in Corn.
Malynda M. Smith*, Anita Dille, Sarah Lancaster, Kraig Roozeboom; Kansas State University, Manhattan, KS (15)

Cover crop potential for weed suppression is influenced by termination timing and species mix in Kansas corn. A field study was implemented in an RCBD with a split-split plot arrangement and four replications at the Kansas State experiment stations near Manhattan, KS in 2019 and near Manhattan and Ottawa, KS in 2020. The objectives were to determine cover crop species and termination time effects on weed density and biomass and to determine the effect of nitrogen availability on late season weed biomass. The whole plot factor was cover crop with cereal (triticosecale x), pea (*Pisum sativum*), cereal + pea ('mixed'), and no cover crop treatments. Subplot factor was termination time at 3 weeks before (3WBP) or at planting (AP) of corn. The sub-subplot factor was N fertilizer applied at rates of 100 kg ha^{-1} or 168 kg ha^{-1}. Nitrogen was broadcast as urea (46-0-0) within one week after planting in both years. Cover crops were terminated with glyphosate (867 g ae ha^{-1}) and 2,4-D (216 g ae ha^{-1}). Cover crop biomass was collected at termination time and weed density was counted weekly from 3WBP through the POST herbicide application, except in Manhattan 2019 where it was counted biweekly. A POST application of atrazine (1121 g ai ha^{-1}), glyphosate (1182 g ae ha^{-1}), and mesotrione (105 g ai ha^{-1}) was made 3 weeks after planting. Weed density and biomass were collected in August 2020 to quantify unsatisfactory control by the POST application. Data were subjected to ANOVA in R (v4.0.2) using the *lmer* function in the lme4 package at significance level (a = 0.05). Means were obtained using the *emmeans* function in the *emmeans* package and Tukey's method for p-value adjustment. Cover crop biomass production ranged from 2500 kg ha^{-1} to 7500 kg ha^{-1} in the mixed and cereal treatments when terminated AP in both years. Weed density was influenced by cover crop and termination time with reductions of 51 to 59% by cover crops compared to no cover and 45% when terminated AP compared to 3WBP. Residues from cover crops terminated AP provided lasting weed suppression with up to 98.9% reduction in weed biomass at grain fill compared to cover crops terminated 3WBP. Greater cover crop residues may compensate for unsatisfactory POST control with extended weed suppression. Compared to no cover treatments, cover type and termination timing impacted yield in 2019 and cover type, termination time, and nitrogen level had an effect in 2020. Future work will examine more closely in-season corn nitrogen status data and implications of the treatment factors on weed suppression and corn yield with a goal to create recommendations for use of cereal cover crops before corn.

Quantifying the Effect of Norflurazon as a Component of Synergistic Tank Mixtures for Control of Multiple Herbicide-Resistant Waterhemp. Kip E. Jacobs*, Seth A. Strom, Dean E. Riechers; University of Illinois, Urbana, IL (16)

Field studies were designed to investigate the potential synergistic effects of the PDS-inhibiting herbicide norflurazon as a component of two- and three-way postemergence (POST) tank mixtures to manage HPPD-inhibitor and atrazine-resistant waterhemp (*Amaranthus tuberculatus*). Experiments were based on the synergistic herbicidal activity commonly achieved when tank mixing HPPD-inhibiting herbicides and PS II inhibitors, but were intended to explore possible benefits of including a carotenoid-inhibiting herbicide with a different target site. Studies were conducted at a location in McLean County, IL containing a multiple herbicide-resistant (ALS-, HPPD-, VLCFA-inhibitors, and *s*-triazines) waterhemp population (designated MCR). POST treatments were applied to plots without a crop and were arranged in a randomized complete block design with three replications in the summers of 2019 and 2020. Treatments included one of three commercial POST applied HPPD-inhibiting herbicides (mesotrione, tembotrione, or topramezone) tank mixed with either a reduced rate of metribuzin, norflurazon, or both to (1) investigate the hypothesis of obtaining increased control of multiple herbicide-resistant waterhemp with two- and three-way tank mixtures, and (2) assess the potential benefit of norflurazon in these tank mixes. Treatments were applied when waterhemp plants were 10 to 12 cm tall, and control was assessed visually 21 days after treatment (DAT) using a scale of 0 (no control) to 100 (total control). Additionally, five randomly-selected plants, at a height of 10 to 12 cm, per plot were marked at the time of application for comparison of biomass accumulation 21 DAT. Results indicated the addition of norflurazon to HPPD-inhibiting herbicides resulted in significant increase in control (approximate mean increase of 30%) than the individual herbicides applied alone. Additionally, metribuzin in combination with HPPD-inhibiting herbicides consistently demonstrated synergistic activity. MCR is resistant to *s*-triazines via metabolic resistance but metribuzin was still effective when applied alone or in tank-mixtures containing HPPD- and PDS-inhibitors. Only the three-way tank mixture containing tembotrione displayed a significant increase in control relative to two-way treatments containing tembotrione, metribuzin, or norflurazon. In summary, results from these experiments add to previous findings of synergy between atrazine and HPPD-inhibiting herbicides and indicate metribuzin in combination with HPPD-inhibiting herbicides is an effective option for POST control of metabolic HPPD- and atrazine-resistant waterhemp populations. The present research also indicates the potential utility of including norflurazon, or possibly other PDS inhibitors, as effective components of two- and three-way mixtures containing HPPD-inhibiting herbicides and metribuzin for managing multiple herbicide-resistant waterhemp populations. Further research in the field, greenhouse, and lab will be conducted to quantify the nature of the interaction among these herbicides in multiple-resistant waterhemp and Palmer amaranth populations.

Widespread Geographic Distribution of Herbicide-Resistant Waterhemp (*Amaranthus tuberculatus*) in Wisconsin. Felipe A. Faleco*, Nicholas J. Arneson, Mark J. Renz, David E. Stoltenberg, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (17)

Waterhemp (*Amaranthus tuberculatus*) is widespread in Wisconsin, and resistance has been confirmed to ALS- (imazethapyr), EPSPS- (glyphosate), and PPO-inhibitor (fomesafen and lactofen) herbicides. However, a comprehensive investigation of waterhemp herbicide resistance status across Wisconsin cropping systems is lacking. Therefore, our objective was to evaluate the response of Wisconsin waterhemp populations to commonly used PRE and POST corn and soybean herbicides, hypothesizing that waterhemp resistance to these herbicides is widespread in Wisconsin. Seed samples from 88 waterhemp populations from 27 WI counties were collected and submitted by stakeholders in the fall of 2018. The greenhouse study was conducted in a RCBD with two experimental runs. Treatments were sprayed in a single-nozzle spray chamber, except for the synthetic auxins, which were sprayed using a CO_2-pressurized backpack spray boom (140 L ha^{-1} spray volume for all applications). The PRE study consisted of 5 herbicide treatments (atrazine 1x = 1121 g ai ha^{-1}; metribuzin 1x = 525 g ai ha^{-1}; fomesafen 1x = 263 g ai ha^{-1}; S-metolachlor 1x = 1785 g ai ha^{-1}; and mesotrione 1x = 270 g ai ha^{-1}) at 0.5x, 1x and 3x the label rate, plus a non-treated control (NTC) for each population. At 28 DAT, plants were counted and biomass harvested. The % stand reduction comparing treatments with NTC was estimated. Populations with stand reduction = 90% were classified as with lack of effective control. The POST study consisted of 8 herbicide treatments (imazethapyr 1x = 72 g ai ha^{-1} + 0.63 v/v % HSOC + 2352 g ha^{-1} AMS; dicamba 1x = 565 g ae ha^{-1}; 2,4-D 1x = 800 g ae ha^{-1}; atrazine 1x = 1121 g ai ha^{-1} + 0.83 v/v % HSOC; glyphosate 1x = 864 g ae ha^{-1} + 2184 g ha^{-1} AMS; glufosinate 1x = 654 g ai ha^{-1} + 2242 g ha^{-1} AMS; fomesafen 1x = 263 g ai ha^{-1} + 0.5 v/v % HSOC + 1428 g ha^{-1} AMS; and mesotrione 1x = 106 g ai ha^{-1} + 0.5 v/v % HSOC + 1428 g ha^{-1} AMS) at 1x and 3x the label rate, plus a NTC for each population. Treatments were sprayed when plants reached 5 to 10 cm in height. At 21 DAT, visual evaluation (VE) was taken on a scale from 1 (dead plant) to 10 (healthy plant) and biomass harvested. Populations with 50% = of treated plants with VE = 5 were classified putative-resistant to the treatment of interest. According to our results, reduced PRE rates (0.5x) resulted in lower waterhemp control for some herbicides. Atrazine did not provide satisfactory control in PRE for most populations evaluated. Imazethapyr and glyphosate-resistant waterhemp is widespread in WI. Putative atrazine-(not widespread) populations and a three-way putative imazethapyr-, glyphosate- 2,4-D-resistant waterhemp population were detected in WI, and will be further investigated. No population was classified as putative dicamba-, fomesafen-, mesotrione-, and glufosinate-resistant. However, we observed random alive plants 21 DAT for these herbicides, except for glufosinate, which provided complete control (100% mortality across all populations investigated).

Differential Gene Expression Between Males and Females in Dioecious *Amaranthus* Species. YouSoon Baek*, Patrick Tranel; University of Illinois, Urbana, IL (18)

Major agronomic weeds in the U.S. include species of *Amaranthus*, specifically waterhemp (*A. tuberculatus*) and Palmer amaranth (*A. palmeri*). These two species are dioecious, and the presence of plants with separate genders forces outcrossing. The outcrossing reproduction system increases genetic diversity in populations and facilitates evolution of multiple resistance, leading to formidable weed management challenges. Therefore, novel weed control strategies, such as genetic control strategies, should be pursued using molecular biology and genomic research. Specifically, a genetic control strategy could be achieved via gender manipulation using a gene-drive system. Conversion of plants to males could theoretically result in local population extinction. Therefore, the research here aims to identify potential gene-drive targets that are responsible for gender determination through RNAseq to capture differentially expressed genes (DEGs) between female and male flowers of these two dioecious *Amaranthus* species. To investigate gender-specific gene expression, total RNA was extracted from three different tissues to represent the different growth stages from each species, including shoot apical meristems (SAM) for the vegetative growth, floral meristems to capture genes at the initiation of flowering, and mature flowers for the later stages of flowering. Two DEGs were identified that were located in the male specific region in each species although the two identified genes were not similar between species. Most DEGs came from autosomal regions and most were differentially expressed in the comparison of mature flowers between male and female. This suggests that each gender may be determined after the initiation of floral development. The gender determination system may inhibit the opposite gender organ development, rather than promoting different floral development. In addition, one gene (*PISTILLATA*) encoding a MADS-BOX protein was upregulated in male compared to female floral tissues and also in male floral tissues compared to male SAM in both species. *PISTILLATA* previously was shown to play a role in male organ development and may play a role in gender differentiation in dioecious amaranths. This research further expands our understanding of gender determination in dioecious waterhemp and Palmer amaranth.

Cover Crop Termination Interacts with Residual Herbicides for Palmer Amaranth Control in No-till Soybean. Isaac N. Effertz*[1], Vipan Kumar[2], Anita Dille[1]; [1]Kansas State University, Manhattan, KS, [2]Kansas State University, Hays, KS (19)

The widespread evolution of herbicide-resistant (HR) Palmer amaranth is serious management concern for soybean growers in the Midwestern United States, including Kansas. Cover crops have shown promising results for pigweed suppression in the moisture-enriched environment in the region; however, little information exist on how to best optimize cover crop termination timing with soil residual herbicides for controlling HR Palmer amaranth in no-till dryland High Plains. The main objective of this research was to determine if the spring termination timing(s) of fall-planted cover crops interact with soil residual herbicides for Palmer amaranth control in glyphosate/dicamba-resistant (GDR) soybean. Field experiments were conducted at Kansas State University Agricultural Research Center near Hays, KS and on a grower's field near Great Bend, KS in 2019 and 2020 growing seasons. Winter wheat cover crop at 67 kg ha^{-1} seeding rate was planted at Hays site, while cereal rye cover crop was tested at Great Bend site. A GDR soybean variety “AG34X7” was planted at 387,543 seeds ha^{-1} at Hays site, whereas, the same variety was drilled at Great Bend site. Experiments were conducted in a split-plot design with four replications. Main plots were comprised of three termination timings: late-April, early May, and mid-May. Split plots included seven herbicide programs comprising glyphosate, glyphosate plus PRE alone, and glyphosate plus PRE followed by (*fb*) POST treatment of glyphosate + dicamba mixture. Data on percent visible control, density, and end of season biomass production of Palmer amaranth were recorded on bi-weekly basis. Soybean injury and grain yields were also assessed. No soybean injury was observed with any of the tested treatments across all site-years. Averaged across two years, cover crop terminated in late-April, early May, and mid-May produced 219, 337, and 733 g m^{-2} biomass at Hays site and 205, 291, 392 g m^{-2} biomass at Great Bend site. Results indicated that the interaction of cover crop termination timing by herbicide programs was nonsignificant for all variables in both locations and only main effects were significant. Averaged across three termination timings, Palmer amaranth density (13 plants m^{-2}) and biomass (361 g m^{-2}) was significantly reduced with glyphosate plus PRE *fb* POST compared to glyphosate alone or glyphosate plus PRE treatments at Hays. Likewise at Great Bend, but on for Palmer amaranth density (52 plant m^{-2}). Delayed termination (mid-May) of cover crops had greatest reduction in Palmer amaranth density (81-100%) compared to early termination timings (late April or early May) at both sites when averaged across herbicide programs. However, grain yield reductions (< 27%) were observed with late-termination timing at Hays site (drier than Great Bend). In conclusions, these results suggest that delay in cover crop termination until mid-May integrated with effective PRE fb POST (two-pass) herbicide program can provide effective season-long control of Palmer amaranth in GDR soybean.

Confirmation of Glyphosate Resistance in a Johnsongrass (*Sorghum halepense*) Biotype from Missouri. Sarah E. Dixon*[1], Justin Pollard[2], Reid J. Smeda[1]; [1]University of Missouri, Columbia, MO, [2]Bayer Crop Science, Camden Point, MO (20)

Repeated application of glyphosate in cropping systems has resulted in selection for many annual species exhibiting resistance. Following an apparent failure of glyphosate to control johnsongrass (*Sorghum halepense*) in soybean, rhizomes were dug from a field in Buchanan County, MO in 2019 and planted into fiberglass trays. Surviving plants from the putative resistant biotype were allowed to grow and develop new rhizomes following an application of 1,736 g ae ha^{-1} of glyphosate. A glyphosate-susceptible biotype was used for comparison in a dose-response assay. Individual plants from both populations were grown in the greenhouse from rhizome pieces buried in pots. When plants reached 15 to 20 cm in height, multiple doses of glyphosate as the potassium salt was applied at 140 L ha^{-1} using an automated spray chamber. At 21 days after treatment, plants were harvested and dry biomass determined. The experiment was a completely randomized design repeated. Dry biomass data were transformed as a percent of control and subjected to non-linear regression using a four-parameter, log-logistic model. The dose to reduce dry biomass by half (GR_{50}) was generated and compared for the putative resistant (R^2=0.76) and susceptible biotypes (R^2=0.81). The susceptible biotype responded as expected to glyphosate, with a GR_{50} value of 203 g ae ha^{-1}. A few plants from the resistant biotype survived doses of up to 6,634 g ha^{-1}. The ratio of the GR_{50} value for the resistant biotype compared to susceptible was 6.5, which agrees with previous reports of glyphosate resistance in johnsongrass. Future work will focus on identifying the mechanism imparting resistance.

Patterns in the Inheritance of Resistance to ALS-Inhibiting Herbicides in Giant Ragweed Infers Link with Self-Incompatibility. Benjamin C. Westrich*[1], Subramanian Sankaranarayanan[1], Sharon A. Kessler[1], Bryan G. Young[2]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, Brookston, IN (21)

Giant ragweed (*Ambrosia trifida* L.) is a highly competitive outcrossing dicot that can pose a significant threat to the optimal yield of many annual crops. Giant ragweed biotypes resistant to acetolactate synthase (ALS)-inhibitors via the dominant W574L mutation can be challenging for soybean growers to control with soil-residual herbicides, as these plants possess high-level resistance that comes at no cost to overall fitness. The ALS gene is encoded in the nucleus, so Mendelian inheritance of this mutation in giant ragweed (2n) is expected. However, previous research identified a population of giant ragweed lacking homozygous mutants, even though the majority of the population (72%) was heterozygous. Possessing two copies of the mutant ALS gene is unlikely to be lethal, as homozygous-resistant giant ragweed plants have been found in other populations. Therefore, we hypothesized that the mutant ALS gene could be linked to a self-incompatibility (SI) allele(s) found in that field population. If such a linkage existed, pollination between resistant gametes would fail because they would also share the same SI allele(s), which would trigger a SI response ending in pollination failure. As no formal SI mechanism has been proposed for giant ragweed, we first compared pollen retention and seed set in cross- and self-pollinated giant ragweed plants to test this phenomena. Cross-pollinated plants retained more pollen grains per style (21, n=97) and set more seed (449, n=6) than self-pollinated plants (5, n=62 and 109, n=4, respectively). Next, we crossed two heterozygous W574L plants from this population to determine whether the progeny would follow Mendelian inheritance and segregate 1:2:1. No homozygous seeds were produced from this cross, confirming past observations in the field. Interestingly, 98 out of 100 seeds were heterozygous, while only two were homozygous susceptible. Similarly, reciprocal crosses between heterozygous and homozygous susceptible plants produced 94% heterozygous and 6% homozygous susceptible progeny (n=200 seeds), when a 1:1 ratio of these genotypes was expected. These results suggest that gametes possessing the W574L mutation are much more likely to be compatible with wild-type gametes because they are linked to different (compatible) SI alleles. Lastly, 65% of the progeny produced from a cross between heterozygous plants from two different populations were heterozygous, while 35% were homozygous susceptible (n=200 seeds), with no homozygous mutants identified. This implies that these two populations possess wild-type ALS alleles linked to different, compatible SI alleles, yet their mutant ALS alleles are still linked to the same (incompatible) SI allele(s). Ultimately, the dramatic overrepresentation of heterozygous progeny found in this study would facilitate a much more rapid spread of resistance than previously expected. This genetic connection may also help researchers to locate an SI gene in giant ragweed, which could be used to directly test for linked inheritance.

Assessment of Industrial Hemp Susceptibility to Off-target Movement of Commonly Applied Corn and Soybean Postemergence Herbicides. Milos Zaric*, Bruno Canella Vieira, Marija Savic, Barbara Vukoja, Guilherme Sousa Alves, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (22)

After the 2018 Farm Bill, industrial hemp has been recognized as a crop legal to grow. Allowance of this commodity to be grown for a variety of purposes (i.e. fiber, grain, hemp oil, cannabinoids, etc.) resulted in increased industrial hemp acreage cultivated throughout the United States. The implementation of industrial hemp fields in areas with adjacent soybean and corn fields raised questions regarding the crop susceptibility to off-target movement of commonly applied herbicides in these crops. At the present time products registered for pest management in industrial hemp are limited. The objective of this study was to examine the sensitivity of industrial hemp to off-target movement of various herbicides registered for use in corn and soybean. This study was conducted in a research wind tunnel at the Pesticide Application Technology Laboratory (University of Nebraska-Lincoln, West Central Research and Extension Center, North Platte, NE). Dual-purpose (grain and cannabinoid) industrial hemp variety was grown under greenhouse conditions. Herbicide solutions (imazethapyr, 2,4-D, dicamba, glyphosate, glufosinate, lactofen, and mesotrione) were mixed at 140 L ha^{-1} carrier volume and sprayed in the low speed wind tunnel (3.6 m s^{-1}) with conventional and air inclusion flat fan nozzles (TP95015EVS and AI95015EVS, respectively) at 207 kPa. Herbicide solutions contained fluorescent tracer (PTSA) at 3 g L^{-1} for fluorometric analysis. During applications, industrial hemp plants (20 – 25 cm) were positioned inside the wind tunnel at different downwind distances from the nozzle (1, 2, 3, 6, 9, and 12 m). Mylar cards (0.01m^2) were positioned along plants to collect spray drift deposits. Plant above ground biomass was harvested at 28 days after treatment and oven dried at 65°C to constant weight. Spray drift deposition was determined for each Mylar card by fluorometric analysis. Spray drift deposition and plant biomass reduction data were analyzed with a four-parameter symmetric log-logistic model using the *drc* package in R software (R Foundation for Statistical Computing, Vienna, Austria). Herbicide drift was influenced by nozzle design ($p < 0.0001$), where applications with conventional and air inclusion nozzles had 5% of the spray deposits reaching 5.9 and 2.0 m downwind, respectively. Industrial hemp had greater sensitivity to glyphosate, glufosinate, and mesotrione spray drift, with plants having 50% biomass reduction at 19.3, 8.7, 9.3 m downwind, respectively, for applications with the conventional flat fan nozzle. Biomass reduction was minimized for herbicide applications with the air inclusion nozzle, with plants having 50% biomass reduction at 4.1, 4.0, and 2.9 m downwind for glyphosate, glufosinate, and mesotrione applications, respectively. Considering that all products evaluated in this study are not labeled for industrial hemp, off-target movement from adjacent corn and soybean fields can be considered as high-risk situation for industrial hemp production. Based on the herbicide sensitivity of this crop, the adoption of additional off-target mitigation techniques is necessary.

Examining Weed Control with Pendimethalin Options for Onion in North Dakota. Harlene M. Hatterman-Valenti*, Collin Auwarter; North Dakota State University, Fargo, ND (23)

A field study was conducted at the Oakes Irrigation Research Facility near Oakes, ND to evaluate crop safety and weed control when applying pendimethalin as a preemergence, delayed preemergence, or early postemergence to onion (*Allium cepa*) in comparison to growers' standard practices. Two long-day onion cultivars, Mondella and Sedona were planted May 1, 2020 on 46 cm centers and a planting population of 625,000 seeds ha^{-1}. First preemergence applications were applied two days after planting (DAP), while the second preemergence applications were applied May 11 (10 DAP) when the onion pellet was cracking and radical beginning to emerge. Early postemergence applications occurred while onions were in the loop stage on May 22 (21 DAP). The first maintenance spray application was June 1 (31 DAP) with GoalTender at 0.29 L ha^{-1} when onions were at the one-leaf-stage. Two weeks later on June 15, the second maintenance application (45 DAP) with Chateau at 525 gm ha^{-1} occurred while the onions were in the three-leaf-stage. Weed control varied among the treatments, and there were some common lambsquarters that were not controlled. One week after the Chateau application the least effective treatments for common lambsquarters were Nortron 1.17 L ha^{-1} and Satellite Hydrocap 0.88 L ha^{-1}. At this time, Prowl H2O applied at the delayed preemergence application (10 DAP) was more effective than when applied at the loop stage (21 DAP). From this time on volunteer soybeans were pulled as they were not controlled with any herbicides applied. Onion stand was poor throughout the trial and could have resulted from a number of factors other than herbicide injury (onion maggot, inconsistent planting seed depth, poor seed germination, or poor seed bed). An exception, was the Nortron 8.18 L ha^{-1} treatment, which severely stunted the onions during the entire season and was included after a misapplication (3.5x) to see if it would injure the crop. This treatment had the lowest total yield with 8.26 Mg ha^{-1} for 'Sedona' and 7.43 Mg ha^{-1} for 'Mondella', almost four times less than the next highest total yield. The greatest total yields for 'Mondella' and 'Sedona' were 43.7 Mg ha^{-1} and 25.2 Mg ha^{-1}, respectively, when treated with Prowl H2O 1.75 L ha^{-1} 21 DAP and Satellite HydroCap 1.75 L ha^{-1} 2 DAP. However, this did not differ from the second greatest total yield of 37.3 Mg ha^{-1} for 'Mondella' when treated with RoundUp 1.61 L ha^{-1} 10 DAP + Prowl H2O 1.75 L ha^{-1} 21 DAP or 24.9 Mg ha^{-1} for 'Sedona' when treated with Prowl H2O 1.75 L ha^{-1} 21 DAP. Even though the Prowl H2O 1.75 L ha^{-1} 21 DAP treatment had poor common lambsquarters control (65%) on May 29, the maintenance applications increased the control to 83% on June 22, which attributed to the treatment with most onion plants having the greatest total yield. Additional trials are planned to examine the consistency of crop safety and weed control when pendimethalin is applied preemergence, delayed preemergence, or early postemergence.

Response of Newly Planted Peppermint (*Mentha x piperita*) to Pyroxasulfone: a Greenhouse Study. Jeanine Arana*, Stephen L. Meyers, Brandi C. Woolam; Purdue University, West Lafayette, IN (24)

Weeds are a problematic pest in mint as they reduce yield of mint hay, oil or both. Additionally, weeds contaminate the mint hay and oil, reducing its quality and value. Despite several registered herbicides in Midwest-grown mint, there is a heavy reliance on herbicides representing only a few mechanisms of action. Pyroxasulfone is registered for use in mint in Pacific Northwestern states, but not in the Midwest. To gain a greater understanding of the effects of pyroxasulfone rate and application timing on peppermint tolerance and yield, two greenhouse trials were conducted from January to April 2020 at the Purdue University Horticulture Greenhouses, West Lafayette, IN. Experimental units consisted of a 20 cm polyethylene pot containing two mint rhizomes planted 2 cm deep. Treatments consisted of a factorial of four rates (110, 220, 440, and 880 g ai ha^{-1}) by three application timings [1 day after planting (DAP) and 2 and 4 weeks after planting (WAP)] plus a non-treated control. Data collection consisted of visual crop injury ratings on a scale of 0% (no injury) to 100% (crop death) and shoot number 14, 28, 42, and 63 DAP. At 28, 42, and 63 DAP height data were collected by measuring the tallest shoot in each pot from the substrate surface to the shoot apical meristem. Mint was harvested 63 DAP and dried at 65 °C for 70 hours. As pyroxasulfone rate increased, crop injury increased and plant height, shoot number, and shoot dry weight decreased. However, when 110 g ha^{-1}, the labeled rate in the Pacific Northwest, was applied at 1 DAP to pots established with two well-branched mint rhizomes (Run 2), no injury was observed at harvest and shoot dry weight was similar to non-treated check. In contrast, when mint was established from less well-branched rhizomes (Run 1), 110 g ha^{-1} of pyroxasulfone reduced shoot dry weight at harvest. Pyroxasulfone at 110 g ha^{-1} applied 2 or 4 WAP caused approximately 10% injury and resulted in decreased shoot dry weight. In conclusion, low rates of pyroxasulfone can significantly reduce newly planted mint yield when applied at 2 or 4 WAP, but high-quality propagation material appears to increase peppermint tolerance to pyroxasulfone if applied at 1 DAP. Additional research should be conducted to evaluate pyroxasulfone in established, dormant mint in the Midwest and to evaluate the influence of mint propagation material quality on tolerance to herbicides.

Herbicide Options for Use in Kernza™ Perennial Grain: IR-4 Update. Clair L. Keene*[1], Eugene P. Law[2], Jacob Jungers[3]; [1]North Dakota State University, Williston, ND, [2]Cornell University, Ithaca, NY, [3]University of Minnesota, St. Paul, MN (25)

Perennial grains hold great promise for reducing the carbon footprint of agriculture by sequestering carbon and reducing soil disturbance. Kernza® is intermediate wheatgrass (*Thinopyrum intermedium*) that has been bred for increased seed yield and is the first perennial grain commercialized in the United States. In 2020, Kernza was grown on approximately 800 ha in the US. Efforts spearheaded by the University of Minnesota and The Land Institute seek to double the area of Kernza cultivation each year for the next ten years. A current constraint to increasing Kernza production is the lack of labeled herbicides that can be used in Kernza destined for human food end-use. Herbicide labels are needed to facilitate Kernza adoption by conventional growers. Trials were initiated in 2019 in Minnesota, Wisconsin, North Dakota, and New York to support IR-4 approval of 2,4-D, clopyralid, and MCPA in Kernza grown for grain. Herbicides and rates tested were 2,4-D amine at 1,065 and 2,130 g ae ha^{-1}, clopyralid at 101 and 202 g ae ha^{-1}, MCPA at 561 and 1,122 g ae ha^{-1}, and clopyralid + MCPA at 101 + 561 and 202 + 1,122 g ae ha^{-1}. In Minnesota, all treatments were applied to established (older than 12 months) and new (less than 3 months old) Kernza stands in fall 2019 and spring 2020; in Wisconsin, treatments were applied to established and new stands in spring 2020; in North Dakota and New York, a subset of treatments were applied in fall 2019 and spring 2020 to new Kernza stands. In fall-applied treatments, visual assessments of injury were taken at 2 weeks after application and again the following spring. In spring applied treatments, injury ratings were taken at approximately 2 and 4 weeks after application. No injury was observed in either the established or new stands of Kernza at Wisconsin for any of the herbicide treatments. Likewise, no injury was observed to the new Kernza stand after the fall or spring applications in New York. In the new stand in North Dakota, some low levels of injury were observed after fall application but no injury was observed by harvest the following summer. Very little injury was observed following the spring application in North Dakota. In Minnesota, low to moderate levels of injury were observed in the old and new stands after the fall application, but all treatments grew out of their symptoms by the following spring. Less injury was observed following the spring application in the old and new stands at Minnesota. In New York, there was no significant difference in whole plant biomass at harvest between the hand-weeded check and the herbicide treatments suggesting that treatments did not reduce Kernza growth. At ND, fall-applied treatments increased head weight compared to the untreated and spring application timings. These preliminary data show that 2,4-D, clopyralid, and MCPA pose little risk to injuring Kernza and are suitable for labeling through the IR-4 program from a crop safety standpoint.

Cucurbit Response to Simulated Dicamba Drift. Lindsey Orphan*[1], S. Alan Walters[1], Karla L. Gage[2]; [1]Southern Illinois University, Carbondale, IL, [2]Southern Illinois University Carbondale, Carbondale, IL (26)

Pumpkins are an important specialty crop in Illinois and are often planted near agronomic crops that are treated with postemergence herbicides, such as dicamba. The objective of this study was to determine the impact of simulated drift rates of dicamba applied at two timings on plant growth and yield of two pumpkin species (*Cucurbita pepo* var. 'Magic Wand', *C. moschata* var. 'Autumn Buckskin'). Field studies were conducted in 2019 and 2020 in Illinois at the Horticulture Research Center in Carbondale. The study used a split-split plot design with 4 replications. Drift rates used were 0, 1/1026, 1/513, 1/256, 1/128, 1/64, and 1/32X, corresponding to 0, 0.00056, 0.00112, 0.00224, 0.00448, 0.00896, and 0.01792 kg ae ha^{-1}. Two applications were made in the month of July approximately one week apart in order for pumpkins to reach the target 8- and 12-leaf growth stages. For both applications, quantitative data to assess plant growth and yield were collected at 7, 14, and 21 DAT, while qualitative data (visual ratings) were collected at 7, 14, 21, 28, 42, and 56 DAT. Pumpkin growth and yield variables collected were vine length, leaf count, adventitious roots, pumpkin weight ha-1, fruit number ha^{-1}, and average individual fruit weight, along with visual ratings such as chlorosis, necrosis, epinasty, injury, and stunt. In 2019, application timing influenced plant growth (leaf count) and yield variables (P<0.05); while in 2020, application timing influenced plant growth variables (leaf count) only. The data suggests that plant growth parameters are reduced at the 8-leaf application timing as compared to the 12-leaf timing, while yield parameters are reduced at the 12-leaf application timing compared to the 8-leaf timing. Simulated drift rates influenced leaf count, total fruit number ha-1, and total fruit weight ha^{-1} in 2019, where the 1/64X treatment was significantly lower in measured variables than the control. During 2019, fruit weight and leaf count were different by species with autumn buckskin producing more leaves and larger fruits. In 2020, average fruit weight and total fruit weight was different by species (P<0.0001), again with autumn buckskin producing larger pumpkins. The results for species were expected, due to the difference in growth characteristics between species. While the lowest drift rates studied did not influence the variables studied, applicators should always follow label requirements and spray with care when in proximity to dicamba-sensitive crops.?

Response of Peppermint (*Mentha x piperita*) to Tiafenacil Applied Post-harvest. Brandi C. Woolam*, Stephen L. Meyers, Jeanine Arana; Purdue University, West Lafayette, IN (27)

Greenhouse experiments were conducted in two runs at the Purdue University Horticulture Greenhouses in West Lafayette, IN in 2020 to evaluate 'Improved Black Mitchum' peppermint response to post-harvest applications of tiafenacil. Peppermint was established in polyethene pots filled with 2.8 L of a 1:1 (v/v) mix of Metromix 510 and sand by rhizomes (Run 1) or stem tip cuttings (Run 2). Peppermint was harvested at the substrate surface with hand shears to mimic field harvest 127 (Run 1) and 69 days after planting (Run 2). Then five rates of tiafenacil (0, 25, 50, 100, and 200 g ai ha^{-1}) plus 0.25% (v/v) nonionic surfactant were applied in a spray booth fitted with a single 8002 EVS nozzle tip and calibrated to deliver 187 L ha^{-1} at 207 kPa. The experiment design was a randomized complete block with four replications. Data collection included visual injury 14, 28, and 49 days after treatment (DAT) and plant height 28 and 49 DAT. Peppermint aboveground biomass was harvest 49 DAT, oven dried for 72 hours, and weighed. Tiafenacil resulted in necrosis of contacted stolon and leaf tissues and delayed regrowth. At 14 DAT predicted mint injury increased from 63 to 86% (Run 1) and 23 to 74% (Run 2) as tiafenacil rate increased from 25 to 200 g ha^{-1}, respectively. Injury at lower rates was transient. At 28 DAT predicted injury increased from 0 to 63% (Run 1) and 2 to 34% (Run 2) at rates of 25 to 200 g ha^{-1}. At 49 DAT, injury from 25 to 100 g ha^{-1} tiafenacil was $\leq$4% and injury from 200 g ha^{-1} was 17%. Compared to the non-treated check, peppermint height at 28 DAT was reduced by 14% with 100 g ha^{-1} tiafenacil and 9 and 10% with 200 g ha^{-1} for Runs 1 and 2, respectively. At 49 DAT, only plants treated with the 200 g ha^{-1} rate displayed a meaningful reduction in height (21%) compared to the non-treated check. Predicted shoot dry weight decreased from 20 to 7 g pot^{-1} as tiafenacil rate increased from 0 to 200 g ha^{-1}. Results of tiafenacil herbicide injury on peppermint and associated crop recovery show potential utility as a post-harvest weed control option at 25, 50, and possibly 100 g ai/ha. However, further research should be conducted to elucidate herbicide application impact on peppermint oil yield and in-field performance on Indiana peppermint and associated weeds.

Buffer Distance Impact on Dicamba Damage to Potato, Tomato and Watermelon. Timothy C. Rice*, Reid J. Smeda; University of Missouri, Columbia, MO (28)

Buffer distance impact on dicamba damage to potato, tomato and watermelon. Timothy C. Rice and Reid J. Smeda Buffer distances between dicamba-tolerant (DT) and dicamba-sensitive (DS) crops have been established at 33.6 m (67 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, 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. DT soybeans were sprayed with dicamba Xtendimax® at 0.56 kg ae ha^{-1} with a prevailing eastern wind. Assessment data included visual injury of tomato, potato and DS soybean from 3-28 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 13% visual injury, with damage higher at the 8.4 m distance and decreasing with increasing distance. 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 at 14 DAT (~16%). Vine growth of watermelon was reduced up to 50% for plants at 8.4 m downwind of DT soybeans. There was no apparent response of tomato or potato yield upwind of DT soybeans at different buffer distances. However, downwind both tomato and potato yields were reduced up to 50% at 8.4 m from DT soybean and yield reductions decreased with increasing buffer distance. In 2020, visual and yield 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.

Response of Winter Squashes and Bell Pepper to Fomesafen Applied PRE. Stephen L. Meyers*, Jeanine Arana, Brandi C. Woolam; Purdue University, West Lafayette, IN (29)

Field trials were conducted to determine winter squash and bell pepper tolerance to fomesafen applied at five rates: 0 (non-treated check), 280, 560, 840, and 1,120 g ai ha^{-1}. Bell pepper (*Capsicum annuum*) research was conducted in a plasticulture production system at the Meigs Horticulture Research Farm in Lafayette, IN. On April 28, raised beds were formed with a between-row distance of 2 m, and black plastic mulch was laid. Fomesafen was broadcast-applied over the top of a plastic-covered row and bare-ground row middles on May 27 using a backpack sprayer fitted with a four-nozzle boom calibrated to deliver 187 L ha^{-1} at 207 kPa. A split-plot design was utilized, with fomesafen rate as the main plot factor and pepper cultivar as the subplot factor. 'Aristotle' and 'PS9928320' pepper plugs were transplanted into a double row on May 29 with 33 cm between rows and 46 cm between plants within each row. Crop injury was recorded 2, 4, 6, and 8 weeks after transplanting (WAP) on a scale of 0 (no injury) to 100% (crop death). Peppers were harvested four times between July 28 and August 19 and graded into fancy, no. 1, and no. 2. Fruit number and weight of each grade was recorded. At 2 WAP, predicted pepper injury increased from 0 to 24% as fomesafen rate increased from 0 to 1,120 g ha^{-1}. Fomesafen at 840 and 1,120 g ha^{-1} reduced plant stand at 4 WAP, equating to 1,322 and 2,415 dead plants ha^{-1}. Fancy and no. 2 fruit number displayed a negative linear response to fomesafen rate and decreased from 33,972 to 30,847 and 88,587 to 66,814 at rates of 0 to 1,120 g ha^{-1}, respectively. Winter squash research was conducted at the Southwest Purdue Agricultural Center in Vincennes, IN. 'Betternut 900' butternut squash (*Cucurbita moschata*) and 'Autumn Delight' acorn squash (*Cucurbita pepo*) were direct seeded into bare ground. Plots consisted of 3 rows, each 6 m long, and 1.8 m apart. Within-row plant spacing was 1.2 m. Injury was rated 2, 4, 6, and 8 weeks after panting (WAP). Squashes were harvest on August 13 and September 12 and graded into marketable and non-marketable. Injury at 2 WAP increased from 5 to 48% at fomesafen rates of 0 to 1,120 g ha^{-1}. By 6 WAP injury was $\leq$9% from all fomesafen rates for 'Betternut 900'. Injury of 'Autumn Delight' was 24% at 1,120 g ha^{-1}, but <6% for all other rates. Pooled across both squash types, predicted yield decreased from 56,393 to 46,007 kg ha^{-1} at rates of 0 to 1,120 g ha^{-1}, respectively. For both crops, fomesafen at the 1x rate (280 g ha^{-1}) resulted in only minimal, transient crop injury and no meaningful reduction in yield.

Impact of Drift Reducing Adjuvants on Spray Pattern Uniformity of Dicamba Tank-Mixtures. Jesaelen Gizotti de Moraes*, Milos Zaric, Guilherme Sousa Alves, Bruno Canella Vieira, Jeffrey A. Golus, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (30)

Dicamba efficiency can be reduced if the appropriate nozzle type, pressure, nozzle spacing, and boom height are not used during applications. Moreover, drift reducing adjuvants (DRAs) added to dicamba tank-mixtures can affect the spray pattern. Therefore, the objectives of this research were to evaluate (1) the impact of two DRAs tank-mixed with dicamba on the solution's liquid physical properties such as density and viscosity, and (2) the effect on spray pattern distribution. Laboratory studies were conducted at the Pesticide Application Technology Laboratory (University of Nebraska-Lincoln, North Platte, NE) using two approved DRAs tank-mixed with dicamba. Treatments consisted of dicamba at of 560 g ae ha^{-1} using a carrier volume of 140 L ha^{-1}. Dicamba was used alone and in tank-mixture with either DRA 1 (guar gum) or DRA 2 (alcohol based with nonionic surfactant in its composition) at 0.5% v v^{-1}. Water alone was included as a control. Applications were made using different nozzles (TTI11004, TDXL11004-D, and ULD12004), operating pressures (138 and 276 kPa), boom heights (60 and 76 cm) and nozzle spacings (50 and 76 cm) combinations using a 12 m^2 horizontal spray table for spray pattern analysis. Coefficient of variation (CV) calculated to characterize the spray pattern uniformity. There was a statistically significant interaction between nozzle, solution, and operating pressure regardless of the sprayer setup configuration being analyzed ($p<0.0001$). The TTI11004 nozzle was the most consistent nozzle across sprayer setup configurations and when operated at 276 kPa using the 50-cm nozzle spacing and a 60-cm boom height provided the lowest CV values (4-12%), followed by the ULD12004 nozzle (5-13%). Increasing the operation pressure contributed to reduced variation from a TDXL11004-D nozzle but it was not sufficient to achieve satisfactory spray patterns (CV<10%). Lowering the spray boom height and increasing the operating pressure were necessary to assure sufficient overlap reducing this variation specially when adding the DRA 1 which showed a higher solution viscosity. Inaccurate doses being applied will have implications on weed control, crop injury, and may contribute to the evolution of resistance.

Influence of Temperature on Droplet Size and Physical-chemical Properties of Glufosinate Tank-mixtures with Different Adjuvants. Joao Victor de Oliveira*[1], Antonio Augusto Correa Tavares[1], Vitor M. Muller Anunciato[1], Estefania Gomiero Polli[1], Rone Batista de Oliveira[2], Greg R. Kruger[1]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Northern Paraná, Bandeirantes, Brazil (31)

Droplet size is a key factor in spray quality and can be modified by spray solution. The physicochemical properties of the spray solution can be modified by the addition of adjuvants or changing the temperature of the spray solution. The objective of this research was to investigate the impact of temperature on combinations of glufosinate with different types of adjuvants on the influence on droplet size, density, and viscosity. The treatments evaluated were glufosinate-ammonium (328 g ai ha^{-1}) applied in a mixture with nine adjuvants: nonionic surfactant (0.37% v v^{-1}), organo-silicone surfactant (0.18% v v^{-1}), high surfactant oil concentrate (0.5% v v^{-1}), modified vegetable oil (0.5% v v^{-1}) drift reduction adjuvant (0.5% v v^{-1}), crop oil concentrate (1.67% v v^{-1}), humectant (0.5% v v^{-1}) and ammonium sulfate (5% v v^{-1}). Solutions were put inside of tote box with water. While increasing the water temperature, using an electric immersion heater, it also increased the solutions temperature (20, 30 and 40 C ± 1 C). Studies were conducted in a completely randomized design with three replications. The droplet spectra study was conducted in a low-speed wind tunnel (6.7 m s^{-1} wind speed) using a Sympatec Helos/Vario KR laser diffraction system. Treatment solutions were sprayed with a single nozzle calibrated to deliver 140 L ha^{-1} using a TT11002 nozzle at 276 kPa. Density and viscosity measurements were made at 20, 30 and 40 C using the fade-out method (DMA™ 4500 M density meter) and Hoeppler's falling ball principle (Lovis 2000 M/ME microviscometer), respectively. For statistical analysis of droplet size, a three-parameter Log-logistic model was performed using R software, fixing the upper and lower limits for the temperature factor, comparing VMD of each temperature of the same spray solution using the studentized t-test with a = 0.05. Density and viscosity were analyzed separately, with the temperature as a factor, and subjected to ANOVA with mean separations made at a = 0.05 level using Fisher's protected LSD test and Tukey adjustment. Glufosinate alone and glufosinate plus DRA has a difference of up to 40 µm as a result of the temperature change (20 to 40 C), and in other cases, glufosinate plus high surfactant oil concentrate and glufosinate plus modified vegetable oil are not different. Changing temperature has an influence on the percentage of fines less than 100 µm, as well as the types of adjuvants, glufosinate plus DRA at 20 C was 0.77%, while glufosinate alone at 40 C was 5.54%. The change in the droplet size due to the change in temperature-dependent with the spray solution. Temperature can cause spray solution to change VMD classification in some cases. Different types of adjuvants modify the physical properties in different ways and decrease density and viscosity when the spray solution temperature increase. Between the analysis of physical properties, only viscosity has some association with droplet size, glufosinate plus DRA had the greatest value in viscosity and lowest percentage of droplets less than 100 µm at 20 and 30 C.

Hooded Sprayer for Application of Nonselective Herbicides in Sugarbeet. Thomas J. Peters*, Alexa Lystad; North Dakota State University, Fargo, ND (32)

Sugarbeet (*Beta vulgaris* L.) producers recognized waterhemp [*Amaranthus tuberculatus* (Moq.) J.D. Sauer] as their most troublesome weed control challenge on 373,064 acres or 59% of the production acreage in Minnesota and eastern North Dakota in 2020. Waterhemp is controlled using soil residual herbicides applied preemergence, early postemergence, and postemergence in sugarbeet. Control is dependent on timely rainfall following application to move herbicides into the weed zone or 2-cm from the soil surface for optimal control. Desmedipham plus phenmedipham or triflusulfuron methyl applied postemergence and inter-row cultivation has been used for waterhemp control when there are performance challenges. However, remnant supplies of desmedipham plus phenmedipham have mostly been exhausted, triflusulfuron methyl resistant waterhemp populations plague the production area, and inter-row cultivation for weed control is not a common production practice. Glyphosate applied through the hooded sprayer in cotton improved weed control while not affecting cotton tolerance. Use of nonselective postemergence sugarbeet herbicides through the hooded sprayer are being evaluated as a control method for herbicide-resistant species and a preemptive solution for palmer amaranth (*Amaranthus palmeri* S. Watson) in sugarbeet. Sugarbeet tolerance and weed control experiments were conducted in 2020 evaluating repeat glyphosate applications and glufosinate or paraquat applied through the hooded sprayer at multiple locations in Minnesota and North Dakota. In the tolerance experiments, stature reduction, number of damaged leaves, root yield, % sucrose, and extractable sucrose were evaluated in response to repeat glyphosate applications at 1.10 kg ha^{-1} plus non-ionic surfactant (NIS) at 0.25% v/v and ammonium sulfate at 2.5% v/v at the 4-leaf stage followed by the 8-leaf stage and glufosinate at 1.76 kg ha^{-1} plus ammonium sulfate at 3.36 kg ha^{-1} or paraquat at 0.84 kg ha^{-1} plus NIS at 2.38 L ha^{-1} through a single 8002 even banding spray tip nozzle (TeeJet® Technologies, Glendale Heights, IL) mounted in the hood and between sugarbeet rows calibrated to deliver 181 L ha^{-1} spray volume at 4-, 8-, and 12-leaf sugarbeet. Glufosinate and paraquat applied at the 4-leaf sugarbeet stage reduced sugarbeet stature at Lake Lillian, MN but caused only negligible damage at Crookston, MN and Prosper, ND. Number of damaged sugarbeet leaves was transient; damage from driving off rows or wheel traffic over lower sugarbeet leaves. Yield components were not affected by herbicides across treatments and timings. In the weed control experiments, control of 5- to 10-cm waterhemp and common lambsquarters (*Chenopodium album* L.) with repeat glyphosate applications at 1.10 kg ha^{-1} plus non-ionic surfactant (NIS) at 0.25% v/v and ammonium sulfate at 2.5% v/v was compared with control of 5- to 10-cm and 15- to 20-cm waterhemp and common lambsquarters with glufosinate at 0.66 and 0.88 kg ha^{-1} plus ammonium sulfate or paraquat at 0.55 or 0.84 kg ha^{-1} plus NIS. Paraquat at 0.55 kg ha^{-1} improved control of 5- to 20-cm waterhemp and glufosinate at 0.88 kg ha^{-1} improved control of 2- to 6-cm waterhemp compared with repeat glyphosate applications.

Comparison of Spray Drift as Predicted by AGDISP with Field Applications Using Air Inclusion Nozzles. Barbara Vukoja*, Guilherme Sousa Alves, Kasey P. Schroeder, Jeffrey A. Golus, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (33)

Droplet size distribution (DSD) is a crucial factor affecting off-target movement. There are several models developed for drift estimation, including AGDISP used by the US EPA. AGDISP estimates downwind spray deposition using several parameters including nozzle type, DSD, and meteorological conditions. The objective of this study was to compare empirical spray drift data collected from a field study with data modelled by AGDISP for air inclusion nozzles. Field applications were made at 276 kPa and 2.4 m s^{-1} travel speed using a 40 nozzle-boom sprayer with 0.76 m nozzle spacing to deliver 140 L ha^{-1}. The nozzles used were ER11004, GA11004, AIXR11004, TDXL11004 and TTI11004 with five replications per nozzle. Mylar cards were used as drift collectors, positioned from 0.5 m to 80 m downwind from the edge of the sprayed area. Spray solution was composed of water with a fluorescent dye (5 g L^{-1}). The tracer was washed from the collectors with a pre-mixture of distilled water and 91% isopropyl alcohol (9:1) and quantified using fluorimetry. Air temperature, relative humidity, wind speed, and wind direction were recorded during the applications to be used for AGDISP modelling. DSD of the nozzles was measured using laser diffraction system, and it will be used as a User-defined input in the AGDISP model. Conventional flat-fan nozzle had greatest downwind deposition up to 9 m from treated area compared to air inclusion nozzles. Air inclusion nozzles had similar downwind deposition beyond 2.5 m from treated area, even though producing up to 312 µm and 2.2% points differences for VMD (Volume Median Diameter) and Pct<141 (Percentage of droplets less than 141 µm), respectively. Air inclusion nozzles are effective tool in reducing spray drift to nearby areas closer to the treated field.

See &Amp; Spray™ Technology Improves Weed Control Input Efficiency. William L. Patzoldt*; Blue River Technology, Sunnyvale, CA (34)

See & Spray™ Technology Improves Weed Control Input Efficiency William L. Patzoldt*; Blue River Technology, Sunnyvale, CA (34). Abstract. See & Spray technology uses computer vision and machine learning (e.g. deep learning) to identify crops and weeds in real-time targeting herbicide applications on weeds rather than broadcasting across the entire field. To demonstrate its utility for weed management in soybean (*Glycine max*) production systems, a field trial was established in York, Nebraska using a soybean variety resistant to 2,4-D, glufosinate, and glyphosate. Treatments consisted of either a 1X or 0.5X rate of a PRE herbicide program using a pre-mix combination of flumioxazin, metribuzin, and chlorimuron-ethyl at 258 g ai ha^{-1} (designated as the 1X rate) followed by several different POST herbicide programs. POST herbicide programs were designated and consisted of: current, 2,4-D-choline at 1070 g ae ha^{-1} plus glufosinate at 657 g ai ha^{-1} applied as a broadcast application; See & Spray, 2,4-D-choline at 1070 g ae ha^{-1} plus glufosinate at 657 g ai ha^{-1} applied using See & Spray; See & Spray enhanced, 2,4-D-choline at 1070 g ae ha^{-1} plus glufosinate at 657 g ai ha^{-1} applied using See & Spray and glyphosate at 870 g ae ha^{-1} applied as a concurrent broadcast application. In addition, each program treatment was applied either with or without a POST-applied residual herbicide, *s*-metolachlor, at 1420 g ae ha^{-1}. See & Spray was able to reduce area treated of POST applications in the plots with estimates of 53% or 63% combined across See & Spray programs when they were preceded by the PRE herbicide program at the 1X or 0.5X rate, respectively. Visual percent weed control ratings of Palmer amaranth (*Amaranthus palmeri*) or green foxtail (*Seteria viridis*) at 21 or 34 DAT suggested no significant differences among the POST herbicide programs (Tukey's HSD; P=0.1; N=4). When comparing across broadcast and See & Spray programs – also accounting for POST applied *s*-metolachlor – the average weed control input savings was approximately \$19 ha^{-1} or \$15 ha^{-1} when using the 1X or 0.5X PRE herbicide rate, respectively. Yield data was also collected, and no significant differences were observed among the treatments with a POST herbicide application (Tukey's HSD; P=0.1; N=4). Collectively, the trial demonstrates a reduction of herbicide input costs can be achieved without a loss of weed control efficacy or yield protection using See & Spray technology in soybean production systems.

Influence of Boom Height on Spray Drift of Herbicides Application. Antonio Augusto Correa Tavares*, Guilherme Sousa Alves, Joao Victor de Oliveira, Rone Batista de Oliveira, Vitor Muller Anunciato, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (35)

The proper configuration of the sprayer during pesticide application is critical to mitigating spray drift potential. Recurrent pesticide drift concerns motivated the development and introduction of new nozzle models on the market. The objective of this study was to evaluate the spray particle drift from ground applications under field conditions with different boom heights. Applications were performed using a 30.5 m boom length self-propelled sprayer equipped with MUG 03 nozzles spaced by 0.76 m. The working pressure was 414 kPa. The tested boom heights were 0.50, 0.75, 1.00, and 1.25 m above the ground level. Rhodamine was added to the sprayed solution at 0.5% v v^{-1} to be detected by fluorometry. Drift collectors (0.2 x 0.2 m Mylar cards) were positioned at different downwind distances from the sprayed area (1, 2, 3, 4, 6, 8, 10, 15, 20, and 40 m). After each application, collectors were individually placed into plastic bags and kept in the dark. Tracer deposits were extracted from samples using 60 mL solution of distilled water and quantified by a fluorometer. By using calibration curves, tracer deposition was calculated (g cm^{-2}). Using a particle size analyzer (Sympatec GmbH, Clausthal-Zellerfeld, Germany) with R7 lens (range 18 to 3,500 µm in diameter). The droplet spectra of MUG03 at pressures of 137, 275, 414, 552, 689, and 827 kPa were compared with TTI11003 and AIXR11003 at the same pressures. The DV50, relative span, and percentage of droplets smaller than 200 µm (driftable fines) were reported. Data were compared using a confidence interval with a=0.05. For all work pressure, the nozzle who generate the highest dv05 was MUG03, followed by TTI11003 and AIXR11003. The dv05 of TTI11003 at 275 kPa had no difference when compared with MUG03 at 552 and 689 kPa. For the lowest work pressure studied, the TTI nozzle showed no difference when compared with MUG and AIXR, but we found a difference between MUG and AIXR. For the pressure, but the two lowest, TTI and AIXR nozzle has the same droplet uniformity. MUG nozzle had the highest uniformity of all nozzles studied. Spray drift was increased as boom height was increased during applications. Applications with 1.25 m boom height had more spray drift deposits (5.77 g cm^{-2}) compared to 1 m (3.41 g cm^{-2}), 0.75 m (1.74 g cm^{-2}), and 0.5 m (1.3 g cm^{-2}) sprayer boom heights. As expected, spray drift deposits decreased as the downwind distance from the treated area increased. Statistically, the treatments had no difference in the distance higher than 4m, but the 1,25 boom height had the highest average, how is shown in the right figure, which represents the influence of boom height on drift collected at distance of 40 m from the treated area. The proper sprayer configuration with lower boom heights and the use of spray nozzles that produce lower driftable fines is an effective technique to mitigate spray drift potential during applications.

A Novel Approach for Decreasing Dicamba Volatility Problems. Donald Penner*, Jan Michael; Michigan State University, East Lansing, MI (36)

In a bioassay system in which various formulations of 2,4-D and dicamba were applied to soybean leaves, volatility was evaluated by inserting tomato plants 0, 3 and 5 days after treatment. Injury to tomato plants from the volatility of Xtendimax, Engenia and Clarity formulations was nearly equal 3 to 5 days after application. Proprietary formulations with riboflavin markedly decreased the volatility. The approach was to use the photolytic action of the riboflavin to inactivate the volatile herbicide vapors.

How Does Weed Density Impact Foliar Herbicide Efficacy? Tomas F. Delucchi*[1], William G. Johnson[1], Bryan G. Young[2]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, Brookston, IN (37)

There are multiple factors affecting a foliar herbicide application and one of them is weed density. Higher weed densities make postemergence herbicide failure more likely and this might be because of overlapping leaves causing insufficient spray deposition to all plants. Plants can distinguish differences in the proximity of other plants through alterations in the spectral intensity of light. Low R:FR as detected by the phytochromes induces shade avoidance syndrome (SAS) responses. These occur at the plant level and 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. Another factor may be 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 trials were conducted in Indiana during 2020 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, thinned before spraying and high densities. The second objective was to determine if tall waterhemp response is different for a non-systemic (glufosinate) versus a systemic (dicamba) herbicide. Spray deposition (µl cm^{-2}) on weeds growing in high density was at least 27% less than the low and thinned densities with no difference between herbicide solutions. This difference was expected and has been cited as the cause of reduced efficacy of postemergence herbicides applied to dense weed infestations. However, despite the differences in spray deposition, glufosinate efficacy on tall waterhemp was the same for the high and thinned weed densities, yet resulted relatively greater in a low density. This observation suggests that the presence of apical dominance, or lateral branching near the base of the plant may also influence the efficacy of foliar herbicide applications. Conversely, the systemic herbicide dicamba resulted in greater efficacy on plants growing in high density compared with plants in the plots thinned prior to herbicide application. Greater spray deposition was observed on the thinned plants compared to high density; therefore, the activity of dicamba was actually greater on plants that had less spray deposition. This research suggests that weed density is a factor that needs to be considered when implementing any postemergence herbicide application. However, an interaction between spray deposition and weed growth related to apical dominance and branching from lower nodes must also be influencing final herbicide efficacy.

The Importance of Adjuvants and Making the Selection Easier. Joe V. Gednalske*; CPDA, River Falls, WI (38)

Most postemergence herbicides often require the use of a tank-mix adjuvant to maximize weed control. Choosing the correct adjuvants has become increasingly more complex do to the large number of adjuvants available and the increase in tank mixes of 3 or more herbicides in a typical application. A review of weed control data shows huge variation in weed control efficacy depending on the adjuvant used. The advantages of using a CPDA Certified Adjuvant is presented to reduce the complexity. A solicitation is presented to the Weed Science Society of America members to assist with more adjuvant research!

Effect of Surfactants on Postemergent Applications of Dicamba, Glufosinate, and 2,4-D on Palmer Amaranth and Kochia. Ely D. Anderson*, Bruno C. Vieira, Jeffrey A. Golus, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (39)

Glufosinate mixed with dicamba or 2, 4-D could help controlling herbicide resistant weeds with two modes of action in a given tank solution. The overall weed control of these herbicides in mixtures could be enhanced with the addition of spray adjuvants. Adjuvants are beneficial to herbicides in tank solution when considering translocation, efficacy, and absorption. Field research was conducted at The University of Nebraska-Lincoln, Pesticide Application Technology Laboratory in North Platte, Nebraska and at the Panhandle Research and Extension Center in Scott Bluff, Nebraska, to better understand the interactions between unformulated glufosinate, 2, 4-D, or dicamba alone and in combination with two proprietary anionic surfactant blends. Palmer amaranth (*Amaranthus palmeri*) was the target weed species in North Platte and kochia (*Bassia scoparia*) was targeted in Scotts Bluff. Weed species were sprayed at 10 to 15 cm tall using a CO2 backpack sprayer calibrated to deliver 140L ha^{-1} using TTI11002 nozzles at 276 kPa. Above ground biomass was harvest and oven dried (65 C) to constant weight at 28 days after application. Biomass data was analyzed using the Colby equation for tank-mixtures of multiple herbicides and ANOVA where means were separated using a = 0.10. Results at the North Platte location indicated that the adjuvants tested did not influence weed control (p-value = 0.74). When herbicides were considered, Palmer amaranth resulted in better control when dicamba was applied alone or in tank-mixture with glufosinate, and when 2,4-D was tank-mixed with glufosinate (>49%). The Scotts Bluff results indicated that the surfactant effect was significant (p-value = 0.05). Surfactant S187 had the greatest kochia control when added to herbicide tank-mixtures (56%). All tank-mixtures applied to Palmer Amaranth and kochia resulted in additivity or synergism. Overall, all herbicide treatments had 60% control on kochia and Palmer amaranth.

Methodology to Estimate and Analyze UAS Swath Width Using Different Application Parameters. Trenton W. Houston*[1], Bradley K. Fritz[2], Wesley C. Hoffmann[3], Greg R. Kruger[1]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]USDA ARS, College Station, TX, [3]Prology Consulting, College Station, TX (40)

Deposition and effective swath width (ESW) for UAS (unmanned aircraft system) pesticide applications have not been determined based on application heights and speeds. The percent coverage values often produced swaths with coefficient of variation (CV) greater than 30%, which is higher than target CV for ground and manned aerial applications. Using the CV to determine the ESW of UAS applications is not feasible because of the high CV values and inconsistent swath patterns. Currently, estimated swath widths are used for UAS applications which results in unknown application volumes and spray deposition. The objective of this study was to estimate ESW for UAS applications based on spray deposition for different UAS flight speeds, heights, and nozzle types. A four rotor UAS was used to apply a tank solution of water and tracer (5 g L^{-1} of bright blue, Spectra Colors Corporation) using AIXR110015, AIXR11002, and AIXR11004 nozzles. Applications were made at 2.2, 2.9, 3.4, 4.4, and 9 m s^{-1} and with flight heights of 1.5, 2.4, and 3 m. Different application speeds and heights were used to identify how swath width and deposition are affected by nozzle selection, flight speed, and flight height. Kromekote cards (3.8x10 cm) were positioned 0.25 meters apart across a 10-m sampling line. Sprayed cards were analyzed using AccuStain (v35.5). ESW and percent coverage were analyzed using an algorithm developed in Spyder (Version 4.1.4). ESW for different nozzles types, application heights, and flight speeds were determined based on the desired application parameter. The UAS deposition swath curves had multiple peaks and elongated deposition ends. The optimal swath widths were produced by changing the distance between adjacent swaths and truncating the ends of the swath where deposition is below one percent. To analyze by a minimum percent coverage value, the ESW is determined by finding the swath width by 2, 4, 6, 8, and 10 percent coverage minimums with the AIXR11002 and AIXR110015 nozzles providing the most consistent spray coverage for the swath width. This allows the swath to be determined by the amount of solution being delivered rather than by CV. The data shows that swath width and deposition are a factor of spray deposition, nozzle type, flight speed, and flight height. This algorithm can be used to analyze UAS deposition data to ensure that effective applications are made with the correct ESW for UAS applications.

The Optify Line of Adjuvants: Versatile Products for a Complicated World. Ryan J. Edwards*[1], Gregory K. Dahl[2], Lillian C. Magidow[1], Mark A. Risley[1]; [1]WinField United, River Falls, WI, [2]WinField United, Eagan, MN (41)

Winfield United launched a new line of adjuvants in 2020, called the OPTIFY line. This lineup is made up of 5 key adjuvants that add flexibility to our portfolio and giving growers more flexibility in a complicated ag space. The products include OPTIFY L27 (Acidifying WC + AMS + NIS), OPTIFY Z37 (Acidifying WC + NIS + MSO), OPTIFY A20 (AMS+NIS), OPTIFY D30 (AMS+NIS+Drift), and OPTIFY XX (AMS free + NIS + DRA). Field data and greenhouse studies were conducted on all 5 products. Results have shown that all the products offer optimal weed control for a wide range of herbicides like glyphosate, glufosinate, 2,4-D and oil loving products.

Dicamba Plus Glufosinate Tank Mixtures Affected by Storage Time and Temperature.
Estefania Gomiero Polli*, Guilherme Sousa Alves, Jesaelen Gizotti de Moraes, Joao Victor de Oliveira, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (42)

Rapid changes in weather conditions may delay herbicide applications which can result in prolonged storage of the herbicide mixture in the spray tank. While the spray solution is in tank mixture, temperature fluctuations and pesticides/adjuvants interactions may decrease herbicide efficacy over time. The objective of this study was to evaluate the influence of storage time and temperature on efficacy of dicamba plus glufosinate (DpG) formulations in tank-mixture alone or with drift control agent (DCA) on common lambsquarters (*Chenopodium album* L.*)* control. Greenhouse studies were conducted at the Pesticide Application Technology Laboratory in North Platte, NE. Independent studies in two temperature ranges were conducted in a complete randomized block design with a 2 x 6 factorial arrangement with 10 replications. Applications were made using dicamba (214 g ae ha^{-1}) plus glufosinate (251 g ai ha^{-1}) alone or with DCA (0.5 v v^{-1}). There were six storage periods: immediate application after mixing spray solution and storage of herbicide solutions for 3, 6, 12, 24, and 48 hours. Glass jars containing the spray solutions were placed in two black boxes. One box was left in a temperature-controlled environment (20 C) and another box was left in natural environmental conditions (20-50 C). C. lambsquarters plants were sprayed at 15 cm using a single-nozzle spray chamber calibrated to deliver 140 L ha^{-1} with AI9502EVS at 345 kPa. Plants were harvested at 28 days after application (DAA) and oven-dried at 65 C until constant weight. Common lambsquarters control decreased 12% over time considering both environmental conditions. However, the solutions stored in natural environment presented less effective control when compared to solutions stored in controlled environment. The presence of adjuvant did not influence weed control over time. To achieve a higher common lambsquarters control, it is necessary to spray the herbicide solution as soon as possible after mixing to avoid prolonged storage and temperature variations of mixed solution in the spray tank.

Reducing Dicamba Buffers in Soybeans with Redball Hooded Sprayers! Steve Claussen*; Willmar Fabrication, LLC, Benson, MN (43)

NO ABSTRACT AVAILABLE

Evaluation of Electrocution as a Method of Controlling Weed Escapes in Soybean. Haylee E. Schreier*, Mandy Bish, Kevin W. Bradley, Brian Dintelmann; University of Missouri, Columbia, MO (44)

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, the Weed Zapper™ was used to test the effectiveness of electrocution on waterhemp (*Amaranthus tuberculatas* (Moq.)) control as a rescue treatment, and its effects on soybean yield. In one experiment, waterhemp was electrocuted at 30.5 cm, 61 cm, flowering, pollination, and seed set. At each electrocution timing, waterhemp plants were electrocuted at speeds of 3.2 or 6.4 km/h, either once or sequentially one week after the first electrocution. Visual weed control ratings were conducted at regular intervals after treatment, which consisted of individual plant and whole plot ratings. Results from this experiment revealed that better waterhemp control was achieved the taller the waterhemp plant, and also when electrocuted sequentially rather than just one time. A second field experiment was conducted in soybean where half of the plots were maintained weed-free, while the remainder contained waterhemp escapes that emerged following a pre-emergence herbicide treatment. Electrocution occurred at the R1, R2, R3, R4, R5, and R6 stages of soybean growth, and at the time of each electrocution the boom maintained nearly constant contact with the upper 8 cm of the soybean canopy. In this experiment, higher waterhemp control was achieved when soybean received electrocution at the R4, R5, and R6 growth stages, primarily due to the fact that escaped waterhemp plants remained smaller than the height of the soybean canopy until R4 or later. Up to 18% visual soybean injury was observed following electrocution, and soybean plants appeared to recover better when electrocuted in the earlier growth stages. When comparing weed-free and weed escape treatments, there is a significant difference in yield. Electrocution at the reproductive growth stages resulted in yield losses up to 26%. 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.

Adoption of UAVs for Pest Management. Emma L. Gaither*, Reid Smeda; University of Missouri, Columbia, MO (46)

Adoption of UAVs for pest management Emma L. Gaither and Reid J. Smeda 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 UAVs 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 · 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 aerially and using a pressurized backpack sprayer at 149.8 L·ha^{-1}. An untreated control was also used. Applications in north-central MO and west-central IL were made at two timings: early August and late September. For August applications, at 8 weeks after treatment (WAT), glyphosate alone and imazapyr plus florpyrauxifen-benzyl resulted in the highest control, but neither treatment exceeded 70% visual control. For the September applications, phragmites control 4 WAT did not exceed 50%, with imazapyr plus glyphosate the most effective treatment. At both timings there was not an initial benefit to the method of phragmites treatment (UAV vs backpack). Because phragmites is a large perennial with an extensive root system, assessment of rhizomes and spring regrowth will more fully determine treatment effectiveness.

Influence of Sodium Cation and Various AMS Adjuvants on the Performance of Various Glyphosate Formulations. Gregory K. Dahl*[1], Amanda Flipp[2], Laura J. Hennemann[2], Joshua J. Skelton[3], Ryan J. Edwards[2]; [1]WinField United, Eagan, MN, [2]WinField United, River Falls, WI, [3]WinField United, St. Paul, MN (47)

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

Non-dicamba Tolerant Soybean Response to Reinstate from Different Cleaning Procedures of Dicamba and Clethodim Tank Mixtures. Vinicius Velho*, Guilherme Sousa Alves, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (48)

Sprayer contamination has been identified as one major cause of off-target movement of dicamba. Injuries can be caused by a superficial cleaning of sprayer tanks and can vary from cosmetic to total yield loss. Tank cleaning procedures should be properly followed for residues be reduced and do not harm susceptible crops in following applications. Because auxin herbicides are difficult to remove from sprayers, tank cleaners have a severe role in breaking down residues facilitating their removal by rinses. The objective of this study was to determine the reinstate of non-dicamba tolerant soybeans to different cleaning procedures of dicamba and clethodim tank mixtures with and without drift reducing adjuvants and tank cleaner. The study was conducted during the 2020 growing season in Stapleton, NE. Treatment structure was 13 x 4 factorial arrangement, being 13 solutions and 4 rinsates. The experimental design used was a RCBD with four repetitions each treatment and the plot size was four feet wide by thirty feet long. Solutions were consisted of combinations of dicamba, clethodim and two different drift reducing adjuvants with and without the use of tank cleaner. Three rinsates were collected and the fourth sample was obtained by filling the tank to simulate a future application. These solutions were sprayed on soybeans at R1 stage using a backpack sprayer calibrated to deliver 140 L ha^{-1} with AIXR 11002 nozzles. Visual injury, plant high at 28 days and at harvest and yield was analyzed using Fisher's Protected LSD test at a = 0.05 using SAS version 9.4. Results observed show a main effect of rinse(p-value<0.0001) and mixture(p<0.0001) and the interaction between rinse and mixture(p-value<0.0001). Visual estimation of injury was noticed on soybean that were exposed to the first three rinsates but not in the follow-up application. Plant height was also significant to solutions and rinsates(p-value<0.0001) and Xtendimax® alone resulted in a higher plant height reduction and visual estimation of injury. The use of tank cleaner was did not affected visual injury and plant height. The use of adjuvants did not impacted the cleanout procedures and soybean response. Triple rinse is important to reduce tank contamination issues and avoid damage on sensitive soybeans and other crops.

Influence of Cover Crops on Soil Microbial Activity and Degradation of Atrazine and Mesotrione. William G. Johnson[1], Lucas Oliveira Ribeiro Maia*[1], Eileen J. Kladivko[1], Shalamar Armstrong[1], Bryan G. Young[2], Joshua R. Widhalm[1]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, Brookston, IN (49)

The use of cover crops has gained popularity over the last few years. The benefits of cover crops are widely documented and include the increase in soil microbial activity. The inclusion of soil residual herbicides at cover crop termination may provide additional weed suppression. However, little is known about the effect of increased microbial activity on the persistence of soil residual herbicides. Two field trials were established in 2019 at Throckmorton and Pinney Purdue Agricultural Centers (TPAC and PPAC, respectively to study the influence of cereal rye (*Secale cereale* L.) and crimson clover (*Trifolium incarnatum* L.) cover crops on soil microbial activity and persistence of atrazine. Treatments included both cover crop species and a fallow control and three levels of soil residual herbicides (no residual, medium and heavy residual). Corn (*Zea mays* L.) was planted as cash crop in the 2020 growing season, three weeks after cover crop termination. Cover crops biomass was determined the day before termination. Soil samples were taken (0 to 5 cm depth) the day before termination, 3, 4, 8, 12, and 16 weeks after termination (WAT). These samples were analyzed for ß-glucosidase (BG) and dehydrogenase (DHA) activities. Atrazine concentration was measured using samples from 3 to 8 WAT. ß-glucosidase activity was not influenced by atrazine concentration in the soil and was affected by cover crop biomass, soil temperature and organic matter content. Averaged across treatments, BG activity was 2-fold more at TPAC relative to PPAC. From 3 to 4 WAT, at TPAC, atrazine concentration was reduced by an average of 82% across cover crop treatments. This research shows he use of cover crops occasionally increased microbial activity. Although more data is needed to support the hypothesis of this study, enhanced degradation of atrazine through microbial activity is widely documented and contributes to the leaching of atrazine metabolites into the surface and groundwater.

Acuron XR Herbicide - Residual Weed Control, Crop Safety and Yield in Corn. Scott E. Cully*[1], Tom H. Beckett[2], Mark J. Kitt[2]; [1]Syngenta Crop Protection, Marion, IL, [2]Syngenta Crop Protection, Greensboro, NC (50)

Acuron XR is a new selective herbicide for weed control in field corn, seed corn, popcorn and sweet corn. Acuron XR contains optimized ratios of bicyclopyrone, mesotrione, *S*-metolachlor and Atrazine that will provide extended residual control of weeds in corn. Field trials were conducted to evaluate Acuron XR for residual weed control compared Acuron and other corn preemergence one pass and two pass products. Results show that Acuron XR will control many difficult weeds in corn and provides consistent, long lasting residual control.

Survey of Stakeholders to Assess Management Practices and Problem Weeds in Nebraska Cropping Systems. Shawn T. McDonald*[1], Debalin Sarangi[2], Jenny Rees[3], Chris Proctor[1], Prashant Jha[4], Amit J. Jhala[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Minnesota, St. Paul, MN, [3]University of Nebraska-Lincoln, York, NE, [4]Iowa State University, Ames, IA (51)

In 2019, Nebraska crop consultants, certified crop advisors, producers, and other stakeholders were surveyed to assess current weed management practices and weed issues. In total 423 responses were received across four extension districts (Northeast, Panhandle, Southeast, and West Central). In total, over half of surveyed farmland (68%) were using no-till practices, among respondents, the majority (61.2%) reported usage of cover crops with cereal rye accounting for 67.9% of total cover crop usage. Corn and soybean production accounted for the majority of crop production accounting for 87.2% of surveyed farmland. Palmer amaranth, common waterhemp, and horseweed were listed as the most problematic weeds across the state. Among stakeholders, 84% of respondents suspected of at least one herbicide-resistant weed. 97% of respondents suspected resistance to glyphosate with 43% suspecting staked resistance to several modes of action (i.e. ALS, HPPD, PS-II, PPO). Respectively 2,4-D, glyphosate, and dicamba were the most reported pre-plant burndown herbicides. Across the state 72% and 61% of corn and soybean growers were using pre-emergence (PRE) herbicides; however, more than 84% of growers reported usage of post-emergence (POST) herbicides for in-season weed control. In corn and sorghum production acetochlor-only, atrazine-only, and their accompanying premix and or tank mixes with bicyclopyrone, clopyralid, mesotrione, and S-metolachlor were widely applied PRE options. In soybean, the most popular PRE herbicides consisted of protoporphyrinogen oxidase (PPO) and acetolactate synthase inhibiting herbicides premix or tank mixes. Glyphosate was the most frequently reported POST herbicide for usage in glyphosate-resistant, dicamba/glyphosate-resistant, and 2,4-D/glyphosate/glufosinate-resistant corn and soybean; 2,4-D and dicamba were the two most frequently reported POST herbicides used in grain sorghum and wheat production. A majority of respondents (65%) reported willingness to adopt herbicide-resistant crops within a year or two of their release while <1% reporting no plans to adopt new herbicide-resistant crops. Survey respondents identified their primary concerns (78%) for future weed science research to focus on herbicide-resistant weed management.

Effectiveness of Group 15 Herbicides for Preemergence Control of Waterhemp (*Amaranthus tuberculatus*) Populations with Differing Sensitivities at Multiple Locations in Illinois. Seth A. Strom*, Kip E. Jacobs, Adam Davis, Dean E. Riechers, Aaron Hager; University of Illinois, Urbana, IL (52)

Group 15 herbicides are extensively utilized for preemergence control of annual grasses and small-seeded broadleaf weeds, such as waterhemp and Palmer amaranth, in agronomic cropping systems. Currently most Group 15 herbicides are applied as herbicide premixes or tank-mixtures with herbicides representing other site-of-action groups. Herbicide combinations can make identification of effective component(s) difficult, especially with soil-applied herbicides. In addition, our group recently reported two Illinois waterhemp populations are resistant to Group 15 herbicides. The goal of this research was to determine the effectiveness of Group 15 herbicides alone for preemergence control of Illinois waterhemp populations. Three locations were chosen including a location in Champaign County with a confirmed Group 15-resistant waterhemp population (designated CHR). Two other locations (Urbana and Perry, IL) contained Group 15-sensitive waterhemp populations. Soils at the CHR and Urbana locations contained greater than 3% organic matter, while the soil at the Perry location contained less than 3% organic matter. At each location, eight Group 15 Herbicides were applied at their minimum and maximum labeled rate according to soil type. Most Group 15 herbicides tested provided poor control CHR 28 days after treatment. Alachlor and non-encapsulated acetochlor provided greater than 90% control 28 DAT, whereas encapsulated acetochlor, dimethenamid-*P*, pyroxasulfone, metolachlor, or *S*-metolachlor provided less than 60% control. In contrast, all Group 15 herbicides provided greater than 88% and 81% control of the Urbana and Perry waterhemp populations, respectively, 28 DAT. Results demonstrate that Group 15 herbicides alone are not adequate for controlling Group 15-resistant waterhemp, but remain an effective resource for control of sensitive waterhemp at locations with high and low organic matter soils. Proper herbicide stewardship and integrated weed management practices incorporating chemical and non-chemical control methods should be implemented to maintain Group 15 herbicides as an effective tool for waterhemp management.

Relationships Among Weed Control, Weather Variability, and Corn Management on Yield Loss Due to Weeds. Christopher A. Landau*[1], Aaron Hager[1], Martin Williams[2]; [1]University of Illinois, Urbana, IL, [2]USDA-ARS, Urbana, IL (53)

Global climate change is creating challenges for agriculture today and will continue in the future. During the past 50 years in the US Cornbelt, average air temperatures have risen and rainfall has become more variable, including an increase in the total number of extreme rainfall events. These trends are expected to continue. Weather and weeds are two stressors that can act simultaneously to affect crop performance, yet their comprehensive study in tandem is limited. The objective was to determine the most important relationships among weed control and weather variability on corn yield loss due to weeds. A database of 215 herbicide evaluation trials containing >2,900 experimental units was used to model the relationship between weed control and corn yield loss due to weeds. The database was used to conduct classification and regression tree (CART) analysis to identify and quantify the effects of potential linkages among weather variability, weed control, and agronomic variables on corn yield loss. An average of 50% yield loss was observed when weeds were uncontrolled; however, yield loss attenuated as percent weed control approached 100%. The final CART model identified late-season weed control as a major driver of corn yield loss, with poor weed control resulting in the highest yield losses. Furthermore, a linkage between weed control and drier, hotter conditions for crop losses was identified. Corn yield losses caused by poor weed control were exacerbated by low water balance and higher temperatures around silking. As the US Cornbelt is heading toward drier, warmer conditions, higher crop losses are more likely without improved effectiveness of weed management systems.

Control of Multiple-Herbicide-Resistant Waterhemp in Corn with Postemergence Herbicides. Darren E. Robinson[1], Peter Sikkema[1], Amit J. Jhala[2], David C. Hooker[1], Christian A. Willemse*[1]; [1]University of Guelph, Ridgetown, ON, Canada, [2]University of Nebraska-Lincoln, Lincoln, NE (54)

Multiple-herbicide-resistant (MHR) waterhemp is becoming increasingly difficult to control due to the evolution of resistance to acetolactate synthase (ALS)-, photosystem II (PS II)-, 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS)- and protoporphyrinogen oxidase (PPO)-inhibiting herbicides. Two field studies were conducted in Ontario in 2019 and 2020 to determine (1) MHR waterhemp control with herbicides applied early postemergence (EPOST) and (2) the interaction between 4-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibiting herbicides and PS II-inhibiting herbicides applied postemergence (POST) for MHR waterhemp control. In study one, all EPOST applications provided 99% to 100% MHR waterhemp control 12 WAA at site (S) 2 and S5. At S1, S3 and S4, all EPOST herbicide applications controlled MHR waterhemp = 90% 12 WAA except glyphosate + *S*-metolachlor/atrazine and glyphosate + dicamba/atrazine that provided 61% to 76% and 63% to 89% control, respectively. In study two, HPPD- and HPPD- plus PS II-inhibiting herbicides provided greater MHR waterhemp control than PS II-inhibiting herbicides at all sites. Mesotrione applied POST controlled MHR waterhemp 54% 4 WAA at S1 and S4, control increased 29%, 34% and 22% with the addition of atrazine, bromoxynil and bentazon, respectively. At S1 and S4, tolpyralate applied POST controlled MHR waterhemp 61%, control increased 20% with the addition of bromoxynil. The addition of atrazine, bromoxynil or bentazon did not increase MHR waterhemp control with topramezone. Colby's analysis indicated synergism between mesotrione and bromoxynil or bentazon and tolpyralate and bromoxynil at S1 and S4. This research concludes that herbicide tank-mixtures applied EPOST can provide full-season MHR waterhemp control. Furthermore, atrazine, bromoxynil and bentazon increased MHR waterhemp control with mesotrione and bromoxynil increased MHR waterhemp control with tolpyralate.

BCS-720: A New Residual Herbicide Combination for Weed Management in Corn. Eric Riley*[1], Mike Weber[2]; [1]Bayer Crop Science, St. Louis, MO, [2]Bayer Crop Science, Indianola, IA (55)

BCS-720 is a new residual herbicide premix developed by Bayer Crop Science for weed management in corn and is currently pending registration with the EPA. This product contains four key components: isoxaflutole, a Group 27 herbicide, thiencarbazone-methyl, a Group 2 herbicide, flufenacet, a Group 15 herbicide, and cyprosulfamide, a safener. BCS-720 will provide broad spectrum residual weed control against common grass and broadleaf species in corn such as amaranths (*Amaranthus sp.*) and foxtails (*Setaria sp.*). BCS-720 will offer a flexible application window from early preplant burndown through the V2 stage of corn. A field study was conducted in 2020, across 28 locations in the US, to evaluate crop safety and residual weed efficacy compared to competitive offerings following applications made at the time of planting. Results from this study indicate BCS-720 can provide excellent crop safety and consistent weed control compared to competitive products. With three herbicide sites-of-action and a novel safener, it will be an effective, safe and consistent weed management tool in corn.

Herbicide Safener Effects on Goss's Wilt Severity in Corn. Nathan H. Haugrud*, Joseph T. Ikley; North Dakota State University, Fargo, ND (56)

Goss's bacterial wilt and leaf blight, caused by the bacterium *Clavibacter nebraskensis*, is a foliar corn disease found in most corn (*Zea mays*) production areas in North America. The disease was confirmed in North Dakota in 2011 and has become the most important corn disease in the state. Goss's wilt is residue-borne, which is especially impactful in North Dakota for two reasons: 1) the increased adoption of no-tillage crop production which minimizes residue break-down and 2) the cold climate allows for less time for residue break-down compared to other corn production states. Isoxadifen-ethyl is an herbicide safener that effectively increases cytochrome P450 activity in corn which enhances a plant's metabolism of herbicide molecules. Recent research found a potential link between isoxadifen-ethyl and increased Goss's wilt severity. A field experiment was conducted in 2020 near Prosper, ND to determine if the presence of isoxadifen-ethyl in corn herbicides increased disease severity. The experiment had two factors: 1) herbicide at eight levels and 2) herbicide application timing at two levels which were two days before and after disease inoculation. For the first factor, four different herbicides were applied with and without isoxadifen-ethyl, which was applied at 26.3 g ha^{-1}. The herbicide treatments were: no herbicide, dicamba at 210 g ha^{-1}, nicosulfuron at 47.3 g ha^{-1}, and topramezone at 18.4 g ha^{-1}. Corn was inoculated at V4 growth stage with a bacterial suspension containing 1 x 10^6 colony forming units of *C. nebraskensis* mL^{-1}. Disease severity was evaluated every 14 days after inoculation until crop maturity to calculate area under disease progress curve. Proportions of systemically infected plants were also collected mid-season and grain yield was collected after maturity. Data was analyzed in SAS using PROC GLIMMIX and means were separated using Tukey's test at a=0.05. Single-df contrasts were used to compare treatments containing isoxadifen-ethyl to treatments without isoxadifen-ethyl. Analysis found no differences between treatments for either disease severity, proportion of systemically infected plants, or corn yield at a = 0.05. Results indicate that choice of herbicide with or without isoxadifen has no effect on Goss's wilt severity and cultural control methods remain the primary disease management strategy.

Acuron GT Launch: T-minus Spring 2021. Ryan D. Lins*[1], Tom H. Beckett[2], Mark J. Kitt[2]; [1]Syngenta Crop Protection, Rochester, MN, [2]Syngenta Crop Protection, Greensboro, NC (57)

Acuron® GT is a new herbicide coming soon from Syngenta for weed control in glyphosate tolerant field corn. Acuron GT will contain *S*-metolachlor, mesotrione, bicyclopyrone and glyphosate for postemergence application with knockdown and residual control of grasses and broadleaves. In 2020, field and greenhouse trials were conducted to evaluate Acuron GT for weed control and crop tolerance. Results show that Acuron GT effectively controls many difficult weeds and provides improved residual control and consistency compared to other commercial standards. Acuron GT is not registered for sale or use in the US and is not being offered for sale.

Assessing the Impact of Drought on Weed Communities and Corn Hybrids with Differing Drought Tolerance. Allyson M. Rumler*, Erin E. Burns; Michigan State University, East Lansing, MI (58)

Water stress is a critical abiotic stress during corn (*Zea mays*) development. While genetic improvements in corn have resulted in hybrids with greater tolerance to abiotic and biotic stressors, it is clear that drought stress is still problematic. Since the commercialization of drought tolerant (DT) corn hybrids, research has documented mixed results on their performance. However, little to no research has been documented on how these hybrids will respond to water stress and weed competition. In addition, while there has been an 11% increase in total precipitation in the Great Lakes Region, this precipitation has become more erratic and intense. With the expected change in precipitation throughout the Great Lakes Region, a field study was conducted in East Lansing, Michigan in 2019-2020 to evaluate the impacts of weed competition and water stress on DT corn hybrid performance and weed community composition and diversity. The study followed a completely randomized design with four replications. Factorial combinations consisted of hybrid (DKC47-27 DroughtGard® or DKC46-20 VT-TriplePRO), weed pressure (weed free, 50% control, or no control), and precipitation (ambient or reduced). Rainout shelters were designed to intercept approximately 70% of total ambient rainfall. Corn growth and development was measured on tagged plants and occurred at four significant growth stages known to be impacted by drought (V4/V6, V12, VT/R1, R3/R4). Weed density by species was measured three times during the season. Weed biomass by species was collected at the end of the season. At harvest, the dominant ear from tagged plants were individually harvested for yield component analysis. Data was analyzed in R using linear mixed effect models and diversity indexes, and data was combined across years. Dominant weed species included: annual grasses, common lambsquarters (*Chenopodium album*), and common ragweed (*Ambrosia artemisiifolia*). Weed density was not impacted by corn hybrid in June or July. However, in July weed density was lower under reduced precipitation than ambient precipitation ($p=0.001$). Furthermore, weed communities under reduced precipitation were more diverse in July than weed communities under ambient precipitation ($p=0.016$), but not significant in June ($p=0.179$). In addition, DS hybrids under ambient precipitation were less diverse than DT hybrids in June ($p=0.023$). Species evenness was more uniform under reduced precipitation in July ($p=0.009$), but not significant in June ($p=0.291$). Additionally, in June, DS hybrids were less even than DT hybrids in both ambient and reduced precipitation ($p=0.008$). There was a significant main effect of weed pressure ($p<0.0001$) and precipitation ($p=0.0072$) for corn yield. Averaged across weed pressures and precipitation, corn yield was not different between DT and DS hybrids ($p=0.893$). Averaged across weed pressures and hybrids, reduced precipitation decreased corn yield ($p=0.007$). Overall, corn yield was reduced by 31% in no weed control treatments compared to corn in weed free or 50% weed pressures. Results demonstrate that reduced precipitation and increasing weed pressure decreases corn yield. Furthermore, reduced precipitation impacts species diversity and evenness greater later in the growing season. Ultimately, integrated weed management will need to adapt to these changes for continued success under future climate scenarios.

Future Efficacy of Preemergence Herbicides in Corn is Threatened by More Variable Weather. Martin Williams*[1], Christopher A. Landau[2], Aaron Hager[2], Patrick Tranel[2], Adam Davis[2], Nicolas Martin[2]; [1]USDA-ARS, Urbana, IL, [2]University of Illinois, Urbana, IL (59)

Earth's climate is changing at an unprecedented rate and many wonder how we can mitigate the worst of climate change and adapt to the rest of it. Even in the Cornbelt, temperatures are increasing and precipitation is becoming more variable. This research questioned how future weather might impact the efficacy of preemergence (PRE) herbicides. Objectives were to 1) determine the risk of reduced efficacy of common PRE products on weeds due to variation in rainfall and soil temperature, and 2) determine the extent to which PRE herbicide combinations improve the success of weed control in variable weather environments compared to individual PRE herbicides. Using a database of ~2,700 herbicide evaluation trials, we modeled the efficacy of atrazine, acetochlor, *S*-metolachlor, and mesotrione, applied PRE alone and in combinations, on three common weed species in corn across 252 weather environments. Rainfall within the first 15 days after PRE application was essential for successful control of common lambsquarters (*Chenopodium album* L.), giant foxtail (*Setaria faberi* Herm.), and waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer). For each treatment, the probability of successful weed control increased as rainfall increased and was maximized when rainfall was = 5 to 10 cm. When rainfall was below this threshold, soil temperature often affected the probability of successful weed control, depending on the herbicides and weed species. Combinations of atrazine, acetochlor, *S*-metolachlor, and mesotrione required less rainfall to maximize the probability of successful weed control and had higher odds of controlling weeds compared to the herbicides individually. Over the next few decades, the US Cornbelt is expected to experience increasing weather variability in ways that are likely to impact PRE efficacy. Using a novel experimental approach, we quantified a critical rainfall threshold within the first 15 days after treatment, and showed that herbicide combinations reduce some risk associated with limited early-season rainfall.

Determination of the Critical Period of Weed Control in an Interseeded System of Corn Silage and Alfalfa. Sarah A. Chu*, Erin E. Burns; Michigan State University, East Lansing, MI (60)

Alfalfa (*Medicago sativa*) acres in Michigan and the Midwest are declining due to reliance on corn (*Zea mays*) silage as a continuous feed source, partly due to low alfalfa yield in the establishment year. By adopting an interseeded corn silage and alfalfa system, farmers can replace the low yielding alfalfa establishment year with corn silage, while simultaneously establishing alfalfa. The objective of this study is to determine the critical period of weed control in the interseeded corn silage and alfalfa system and how this impacts alfalfa yield in the following full production year. Therefore, a field study was conducted in East Lansing, MI in 2019- 2020. The study followed a randomized complete block design with four replications. Whole plots were assigned to one of two corn silage hybrids with differing leaf architecture: upright (narrow leaf angle) vs. pendulum (wide leaf angle). Subplots were assigned to one of eight weed removal or addition timings. A glyphosate tolerant variety of alfalfa was planted on the same day as the corn. Japanese millet (*Echinochloa esculenta*), a surrogate weed, was used to establish uniform densities and emergence patterns. Treatments to establish the critical period of weed removal (CPWR) allowed weeds to emerge with the alfalfa/corn at planting followed by removal with glyphosate at 2, 4, 6, and 8 weeks after planting. Treatments to establish the weed-free period were maintained weed-free with glyphosate until 2, 4, 6, and 8 weeks after planting, at which time the millet was planted. Weed-free and weedy plots were included as controls. At the end of the interseeding year (hereafter year 1), corn silage was harvested, alfalfa remained the following year (hereafter year 2). Data for the critical period of weed control was analyzed in R using the drc package. Four and three-parameter log-logistic models were used to calculate a 5% acceptable corn yield loss. Alfalfa yield was analyzed using a linear mixed effects model in R and means were separated using Tukey's HSD. The CPWR was statistically different between years (p=0.0006), therefore years were analyzed separately. In 2019, there was no difference in the CPWR between hybrids (p = 0.95). The CPWR in 2019 occurred at 399 GDD averaged across hybrids. In 2020, there was no difference in the CPWR between hybrids (p=0.90). In 2020, the CPWR was 709 GDD averaged across hybrids. Alfalfa yield was significantly different between cuttings (p=0.03); therefore, cuttings were analyzed separately. The first alfalfa cutting yield decrease by 51% from the year 1 legacy weedy treatment and by 44% in the year 1 legacy week eight removal timings when compared to the year 1 legacy weed free treatment. Similar trends were observed in the second and third cuttings; however, by the fourth cutting there was no significant differences between year 1 legacy treatments (p=0.2). Thus, to maximize corn yield the CPWR is V5 corn, while the removal time to maximize alfalfa yield should occur at V10. Weed control is important in the interseeded system to achieve high yields in both alfalfa and corn.

Survey Update on Herbicide-Resistant Palmer Amaranth in Kansas. Vipan Kumar*, Rui Liu, Taylor Lambert, Phillip W. Stahlman; Kansas State University, Hays, KS (61)

Evolution of herbicide-resistant (HR) Palmer amaranth (*Amaranthus palmeri*) and common waterhemp (*Amaranthus tuberculatus*) is serious management concern for Kansas growers. Since 2014, a field survey was initiated to collect seeds of Palmer amaranth and common waterhemp from agronomic crops across Kansas to determine the frequency and distribution of herbicide resistance in both weed species. The main objectives of this research were to (1) determine the resistance frequency (as percent resistance within a population) in 20 Palmer amaranth and 9 waterhemp populations from Kansas soybean fields to discriminate-dose of glyphosate, 2,4-D, glyphosate + 2,4-D choline premix (Enlist Duo®), dicamba, glufosinate, fomesafen, atrazine, and chlorsulfuron; and (2) highlight alternative strategies for managing HR Palmer amaranth in soybean. For objective 1, seedlings of each selected Palmer amaranth and waterhemp population were grown in 5- by 5-cm size cells within a plastic tray (total 50 cells $tray^{-1}$) filled with a commercial potting mix in a greenhouse at Kansas State University Agricultural Research Center (KSU-ARC) near Hays, KS. Actively growing seedlings (7- to 9-cm tall) from each population were separately treated with discriminate dose of glyphosate (1260 g ha^{-1}), 2,4-D (870 g ha^{-1}), glyphosate + 2,4-D choline (1071 + 1008 g ha^{-1}), dicamba (560 g ha^{-1}), glufosinate (655 g ha^{-1}), fomesafen (395 g ha^{-1}), atrazine (1120 g ha^{-1}), and chlorsulfuron (26 g ha^{-1}). Based on percent survival data collected at 21 days after treatment (DAT), resistance to glyphosate, 2,4-D, glufosinate, mesotrione, fomesafen, atrazine, and chlorsulfuron was observed in 12, 7, 13, 18, 9, 20 and 18 Palmer amaranth populations (out of total 20 populations) with resistance frequency of 20 to 80%, 20 to 30%, 22 to 44%, 24 to 64%, 20 to 67%, 24 to 76% and 25 to 65% respectively. None of the tested Palmer amaranth populations showed resistance frequency of >7% and >11% with a discriminate dose of dicamba and glyphosate + 2,4-D, respectively. Similarly, resistance to glyphosate, dicamba, mesotrione, atrazine, and chlorsulfuron was observed in 10, 1, 6, 4, and 8 waterhemp populations (out of total 9 populations) with resistance frequency of 92 to 100%, 33%, 24 to 85%, 41 to 98%, and 22 to 100% respectively. Results from various field studies have shown that PRE applied premixes or tank-mixtures containing herbicides from multiple sites of action followed by a POST application of labelled herbicide (dicamba plus glyphosate in Xtend soybeans; 2,4-D plus glyphosate or glufosinate in Enlist E3 soybeans; and glyphosate plus glufosinate in GT27 soybean) can provide excellent, season-long control of HR Palmer amaranth. In addition, results from field studies have also shown that proper termination of fall-planted cereal rye with effective soil-residual herbicide can help controlling HR Palmer amaranth in no-till dryland soybean production in Kansas. In conclusion, these results suggest that resistance to commonly used herbicides (glyphosate, mesotrione, atrazine, and chlorsulfuron) is evident in Palmer amaranth and waterhemp populations in Kansas soybean fields. Diversified weed control strategies need to be adopted to tackle the increasing problem of HR Palmer amaranth and waterhemp.

Bicyclopyrone Use Patterns in Minor Crops. Scott A. Payne*[1], Timothy L. Trower[2], Eric K. Rawls[3], Tom H. Beckett[4], Pete M. Eure[4]; [1]Syngenta Crop Protection, Slater, IA, [2]Syngenta Crop Protection, Baraboo, WI, [3]Syngenta Crop Protection, Vero Beach, FL, [4]Syngenta Crop Protection, Greensboro, NC (62)

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

Screening of Industrial Hemp (*Cannabis sativa*) Tolerance to Corn and Soybean Herbicides. Haleigh J. Ortmeier-Clarke*, Maxwel Coura Oliveira, Nicholas J. Arneson, Shawn P. Conley, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (63)

Since the passing of the 2014 and 2018 Farm Bills, interest in industrial hemp (*Cannabis sativa* L.) has increased in the state of Wisconsin. However, 50 years have passed since Wisconsin last produced the crop for its grain or fiber. Thus, growers have many questions surrounding best management practices, especially around weed management. Currently there are no synthetic herbicides registered for use on industrial hemp in the United States. The objective of this study was to evaluate the response of industrial hemp to commonly used corn and soybean herbicides at different doses. The dose-response greenhouse study was conducted with two cultivars (CRS-1 and X-59) in a completely randomized design (CRD) with three replications. A total of 7 doses (0.125x, 0.25x, 0.5x, 0.75x, 1x,2x, and 4x label rate) were tested for each of the 23 PRE- and 21-POST emergence herbicides across 11 sites of action evaluated in this study. Experiments were replicated twice in time. Visual evaluation was conducted 21 and 28 days after treatment for POST- and PRE-emergence treatments, respectively. Results from two herbicides, clethodim (SOA 1) and clopyralid (SOA 4) are presented. The 1x clethodim and 1x clopyralid rates caused 16.6% and 21.5% biomass reduction, respectively. Injury was relatively low and the crop was expected to recover. All remaining POST-emergence herbicides evaluated caused >75% biomass reduction at their respective 1x rate. Data from this study can help researchers target which herbicides should be further investigated under field conditions as potential options for chemical weed control in industrial hemp. These results can also provide baseline guidance on industrial hemp sensitivity to drift and carryover from herbicides commonly used in corn and soybean production.

Structured PRE and POST Programs for Crop Tolerance and Weed Control in Industrial Hemp. Stevan Knezevic*[1], Ivan B. Cuvaca[2], Rodrigo Werle[3], Jon Scott[2]; [1]University of Nebraska-Lincoln, Concord, NE, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]University of Wisconsin-Madison, Madison, WI (64)

Nebraska legalized industrial hemp in 2019, which created much interest in researching various aspects of hemp production, including weed control. Therefore, we initiated study at Agronomy Farm in Mead (NE), with the objective to test hemp tolerance to several PRE and POST herbicides commonly used in corn or soybean. The experiment was laid out in a RCBD arrangement of 23 treatments with three replicates. Industrial hemp (variety X-59 for fiber) was planted on June 8, 2020 in 75 cm rows, 2 cm deep and at about 50 thousand seeds per ha. The PRE treatments were applied one day after hemp planting, compared to POST treatments at the 20-25cm of hemp height. Hemp injury ratings were conducted at 15, 21, and 28 days after treatment (DAT) in PRE and 6,13 and 20 DAT for POST herbicides, utilizing the scale from 0-100 (0=no injury; 100=dead plant). Visual injury levels ranged from no injury (0%) to temporary injury (<20%), and in few cases, the severe injury or death (>50%). No hemp injury was evident in plots sprayed PRE with 30 g ai/ha of Sharpen (saflufenacil) or 70 g ai/ha of Stinger (clopyralid), which appeared to be the most promising PRE herbicides for hemp production, at least from the list we tested. Temporary hemp injury, which lasted first two weeks, was evident in multiple plots, in the form of leaf yellowing. For example, Dual II Magnum (S-metolachlor @ 1788 g ai/ha) or Hornet (flumetsulam + clopyralid @ 96g ai/ha), or Python (flumetsulam @ 25.9 g ai/ha) applied PRE caused 8-20% visual injury at 15 DAT, however by 21 DAT most of those injuries were reduced to about 5%, and by 28 DAT to zero, indicating hemp recovery. From POST products, 52.4 g ai/ha of Assure II (quizalofop), or 1788g ai/ha of Dual II-Magnum or 157 g ae/ha of Stinger (clopyralid) were the safest causing temporary injury of up to 10%. Severe hemp injury (50-100%) was caused by POST application of 96 g ai/ha of Hornet and 420.3 g ae/ha of Moxy 2E (bromoxynil) applied POST, thus they should not be used.

Exploratory PRE and POST Treatments for Crop Tolerance in Industrial Hemp. Jon Scott*[1], Ivan B. Cuvaca[1], Stevan Knezevic[2]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Concord, NE (65)

Nebraska legalized industrial hemp in 2019, which created considerable interest in researching various aspects of hemp production, including herbicides for weed control. Therefore, we initiated a study at the Agronomy Research Farm in Mead, NE with the objective to test hemp tolerance to PRE and POST herbicides from several site of action groups including 2, 3, 4, 5, 6, 13, 14, 15, and 27. The study was terminated at pollination to prevent volunteer hemp plants. Experiments were conducted as a randomized complete block with three replications. Plots consisted of 4 rows with the center two treated and were 3 x 7.6m. Industrial Hemp (X-59 for fiber production) was planted at 50,000 seeds ha^{-1}. PRE treatments were applied one day after planting (DAT) and POST treatments were applied to 25-50 cm tall hemp. Visual ratings were taken at 15, 28, and 49 DAT for the PRE and 6, 13, and 20 DAT for the POST utilizing the 0-100 scale, where 0 = no injury to 100 = complete death. Visual injury levels ranged from no injury (0%) to visible injury (<30%), and in several cases, severe injury or death (>45%). PRE applications of halosulfuron, pendimethalin, flumioxazin, and sulfentrazone showed promise with 28 DAT ratings below 5%, while clomazone and isoxaflutole did cause complete death of the hemp plant. For POST applications, injury ratings varied greatly in each herbicide classification group except group 2, which exhibited unacceptable injury for all products tested. For group 4 herbicides, clopyralid and quinclorac displayed initial injury, then recovered, while fluroxypyr was extremely phytotoxic. Interestingly, the 2+4 combination herbicide flumetsulam+clopyralid was injurious to hemp. In group 6 herbicides, bentazon was damaging while bromoxynil could possibly be a rescue treatment, if some injury could be tolerated. Group 14 stand-alone herbicides point to flumiclorac's potential, while fomesafen and lactofen caused 45% and 37% injury, respectively, at 20 DAT. Group 14+15 combination herbicides also have potential as a rescue treatment, and to provide residual, however it is not clear why fomesafen+acetochlor did not cause as much injury as fomesafen applied alone. Please note that the above conclusions are based only on one year of data, thus certain treatments will be repeated in 2021 season.

Phytotoxicity of Industrial Hemp (*Cannabis sativa* L.) Extracts. Avery Shikanai*, Karla L. Gage; Southern Illinois University, Carbondale, IL (66)

Industrial hemp (*Cannabis sativa* L.) is reportedly a competitive crop that may suppress weeds once the crop is established. Allelopathy, the chemical inhibition of one plant by another, is a mechanism which could explain hemp's competitiveness and may provide additional value in a crop rotation. Previous work has demonstrated the phytotoxicity of individual cannabinoids and terpenes, major constituents of hemp. However, any allelopathic properties of whole hemp are poorly characterized. Therefore, the goals of the present study are to characterize the phytotoxicity of whole hemp extracts, and to determine if hemp residue can suppress weed emergence. To test phytotoxicity of hemp-derived chemicals, an extract was prepared by sonicating hemp inflorescences in acetone. After solvent removal, the extract was emulsified in Tween-20. Twenty surface-sterilized seeds of a bioindicator species, kale (*Brassica napus* var. *pabularia* 'Red Russian'), were placed on a filter paper moistened with hemp extract diluted to 0.005, 0.01, 0.1, 0.5, 1, 2.5, and 5mg mL -1 . Treatments were replicated 10 times and placed in a growth chamber. To test the ability of hemp residue to suppress weed emergence in more realistic conditions, 50 common waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer) seeds and one of three treatments was added to the surface of soil in a 11.5 cm x 11.5 cm pot: 1) no residue, soil alone, 2) 5 g ground corn residue (control), or 3) 5 g of ground hemp residue. Treatments were replicated 5 times, and germinated seedlings were counted and removed over time. Results of a one-way ANOVA suggest that in laboratory conditions, 5 mg mL^{-1} hemp extract significantly reduced germination of kale. The average number of kale seeds that germinated per experimental unit decreased from 8.7 in the control to 2.6 in the 5 mg mL^{-1} treatment. Results of the greenhouse study suggest that addition of 5 g hemp residue to the soil surface significantly reduced the germination of waterhemp in comparison to the no residue control (Cox proportional hazard regression; hazard ratio = 0.09, $P<0.001$) and the corn residue treatment (hazard ratio = 0.71, $P=0.03$). These results suggest that hemp produces phytotoxic chemicals, and that hemp residue may suppress weed seedling emergence. Further work is needed to determine if hemp can be used in a rotational strategy to suppress weeds. Suppression of waterhemp by hemp residue suggests that chaff-lining may be a potential weed management tool in a hemp row crop scenario.

Industrial Hemp Variety Tolerance to PRE-Herbicides. Ivan B. Cuvaca*[1], Amit J. Jhala[1], Jon Scott[1], Stevan Knezevic[2]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Concord, NE (67)

Industrial hemp (IH) is a variety of the Cannabis sativa plant species that is grown in more than 30 nations for its fiber and oilseed. In the U.S., IH is getting more attention lately as at least 46 U.S. states work on legalizing its production. However, herbicides registered for in-season weed control in hemp are scarce. To help address this issue, a greenhouse study was initiated in June and repeated in August 2020 to test tolerance of three IH varieties to PRE herbicides commonly used in corn and soybean. The study was laid in a randomized complete block design with a split-plot arrangement of treatments. Main plots consisted of 14 soil-applied herbicides and subplots consisted of three IH varieties: Cherry Wine, Canda and Delores. Each treatment was replicated three times. The seeds were placed 1.3 cm deep in 53.3 cm*38.1 cm*10.1 cm trays filled with a loamy textured soil. Each tray consisted of three rows of IH 12.7 cm apart with each variety planted at a density of 30 seeds per row. Herbicide was sprayed immediately after sowing and then activated with 1.27 cm of irrigation water. Irrigation water was supplied daily as needed. Visual injury was assessed at 7, 14 and 21 d after treatment (DAT) using a scale ranging from 0% (no injury) to 100% (plant death). In general, injuries varied from yellowing to leaf bleaching. All three IH varieties were equally sensitive or tolerant to tested herbicides. Sharpen, Permit, Prowl H_2O and Valor EZ caused light and temporary injuries within the first 7 DAT; past that, no injury was evident in any of the three varieties tested indicating complete recovery. Stinger, Sulfentrazone 4F and Surpass NXT caused temporary injuries (4-15%); therefore, these products could be used for in-season weed control in hemp but with caution. Python, Dual II Magnum and Surestart II caused unacceptable injuries ranging from 25-40%, while Balance Flexx, Tricor 4F and Command caused injuries over 90%; therefore, these products should be avoided.

Fall-seeded Cereal Rye Suppresses Horseweed in Sugarbeet. Brian Stiles*[1], Christy Sprague[2]; [1]Michigan State University, Durand, MI, [2]Michigan State University, East Lansing, MI (68)

Limited herbicide options make glyphosate-resistant horseweed (*Erigeron canadensis* L.) a weed control challenge for Michigan sugarbeet farmers. Cereal rye has been shown to suppress horseweed in several crops. In 2019 and 2020 field studies were conducted in East Lansing, Michigan to evaluate the effects of integrating a fall-planted cereal rye cover crop with glyphosate and clopyralid-based weed control programs for horseweed management in sugarbeet. 'Wheeler' cereal rye was drilled at 67 kg ha^{-1} in fall of 2018 and 2019. This study was established in a split-plot design with cereal rye termination method and time as the main plot factor and herbicide treatment as the sub-plot factor. Cereal rye treatments included: early burndown (EBD) 14 d prior to sugarbeet planting, burndown at planting (PBD), PBD + roller, and PBD + roller crimper, a delayed burndown (DBD) 7 d after planting, and a no cover control. The burndown treatments consisted of glyphosate applied at 1.27 kg ae ha^{-1} + ammonium sulfate. The three herbicide 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 the time of termination was 640 and 346 kg ha^{-1} in 2019 and 2020 for the EBD termination, respectively. Cereal rye biomass at planting was 740 and 745 kg ha^{-1} in 2019 and 2020, respectively, and biomass was 5- and 2.5-times higher at the time of Planting Green termination in 2019 and 2020, respectively. By mid-July, regardless of termination time or method horseweed biomass was at least 38-64% lower than the no cover control in both years. 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 horseweed suppression at sugarbeet harvest did not last throughout the season and none of the cover crop treatments resulted in less horseweed biomass than the no cover control. Averaged across herbicide treatments, the at plant termination timing was amongst the highest for sugarbeet yield in both years. In both years, the no cover control and Planting Green were amongst the lowest sugarbeet yields. Lower yields were likely due to greater horseweed pressure in the no cover control and early-season competition with cereal rye from the Planting Green treatments. Even though integrating cereal rye to suppress horseweed early in the season in sugarbeet production systems have shown positive results, it will be important to further examine how these strategies can be refined to improve horseweed suppression, while maintaining sugarbeet yield.

Comparison of Available ACC-ase Inhibiting Herbicides for Use in Industrial Hemp.
Marija Savic*, Milos Zaric, Jeffrey A. Golus, Kasey P. Schroeder, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (69)

Comparison of Available ACCase Inhibiting Herbicides for Use in Industrial Hemp Marija Savic, Milos Zaric, Jeffrey A. Golus, Kasey P. Schroeder, Greg R. Kruger Industrial hemp *Cannabis sativa* L. (fam. Cannabaceae) is an annual broadleaf plant grown for fiber, grain, and cannabinoid production. Industrial hemp from legal standpoint cannot contain more than 0.3% tetrahydrocannabinol on dry weight basis. Industrial hemp thrives in soil conditions that are favorable for corn production. In 2018 Farm Bill allowed expansion of hemp growth under certain requirements but even with this production hemp is now widespread and area of cultivation is increasing continuously. At the present there is no synthetic herbicide registered for use in industrial hemp in the United States. Considering the selectivity of Acetyl CoA Carboxylase (group 1) to control grass weeds in broadleaf crops, the objective of this study was to evaluate the crop safety of this herbicide group on industrial hemp. Herbicides selected for this study included clethodim, fenoxaprop, fluazifop, fluazifop + fenoxaprop, pinoxaden, quizalofop, and setoxidim. Based on manufacturer recommendations for other crops herbicides were applied in three doses (1x, 2x and 4x label rate). This study was conducted in a randomized complete design with nine replications. Industrial hemp plants (dual purpose variety for grain and cannabinoid production) were grown under greenhouse conditions. Herbicide applications was performed when plants were 25-30 cm height using a single-nozzle research spray chamber calibrated to deliver 140 L ha^{-1} using a DG9502EVS nozzle. After plants were harvested at 21 DAA they are oven dried at 65° C to reach a constant weight. Dry biomass weights were recorded and used for further analysis. Dataset was analyzed with a generalized linear mixed model in SAS (Statistical Analysis Software,version 9.4, Cary, NC, USA) with treatment comparisons performed using a Tukey's test at significance level a = 0.05.The results of this study suggest that sensitivity of industrial hemp to group 1 herbicides was dose dependent (p=0.0045). Therefore, simple effect comparisons within each dose were performed to determine where are those differences. In comparison of non-treated control within each herbicide at 1x dose the only difference was determined for pinoxaden. Further, as dose increased for active ingredient like clethodim it seems that as product rate in tank-mixture increase plant biomass decreases. Across all examined doses and herbicides evaluated the only treatment which did not impact industrial hemp biomass was observed with quizalofop. With diversity in sensitivity of industrial hemp plants to group 1 needs to be explored further to determine whether they can be used safe or not by including assessment of other parameters. This might not represent a problem for industrial hemp grown for fiber and grain, however, considering that ACCase inhibiting herbicides are directly blocking fatty-acid synthesis it is necessary through future studies to determine how those herbicides may impact oil profiles in plants grown for cannabinoids.

Weed Control and Cabbage/Cauliflower Response to Pyridate. Sushila Chaudhari*, Bernard Zandstra, Nicole Soldan; Michigan State University, East Lansing, MI (70)

The investigation of potential herbicides for weed control in cabbage and cauliflower (cole crops) is critical due to the limited number of registered herbicides, especially for postemergence application (POST). Pyridate, labeled as Tough 5EC in field corn, chickpea, and mint, is a photosystem II inhibitor. Pyridate injury, which occurs as distinctive, blotchy chlorosis of treated leaves, has frequently been reported in cole crops, but with no effect on yield. Changing herbicide formulation has improved weed control or improved crop safety. Another pyridate formulation, Lentagran 45WP, was developed with the aim to improve crop safety and registered to use in cabbage, Brussels sprout, and bulb onions in other countries, but is not registered in the USA. There is limited information on the impact of pyridate formulations on cole crops safety. Therefore, field studies were conducted at the Horticulture Teaching and Research Center, East Lansing, MI during 2019 and 2020 to determine crop safety and weed control from two formulations of pyridate applied POST in cabbage and cauliflower. Two formulations were included: emulsifier concentrate (Tough 5EC) and wettable Powder (Lentagran 45WP). During both years, *S*-metolachlor 1.45 kg ai/ha was applied one day before transplanting of cabbage (Blue Vantage) and cauliflower (Candid Charm). Both pyridate formulations were applied at 0.52, 0.69, 1.0 kg ai/ha at 45 and 30 days after transplanting in 2019 and 2020, respectively. The experimental design was a RCBD with three replicates. Visual crop injury and weed control were recorded based on a scale of 1 (no crop injury, no weed control) to 10 (crop death, complete weed control). At 14 days after treatment (DAT), pyridate EC formulation caused higher injury than WP formulation when compared for same rates during both years. However, in 2020 at 28 DAT, crop injury was <1.7 regardless of type of formulation. Pyridate provided excellent control of common lambsquarters (=8.3), common purslane (10), and ladysthumb (=8.7) and fair control of common ragweed (=5.7) regardless of type of formulation. There was no effect of herbicide treatment on cabbage and cauliflower yield in both 2019 and 2020. Based on these results, pyridate WP formulation is safe to use in cabbage and cauliflower.

Sunflower, Dry Pea, Chickpea, and Lentil Tolerance to Fall-Applied 2,4-D and Dicamba.
Brian Jenks*[1], Caleb D. Dalley[2]; [1]North Dakota State University, Minot, ND, [2]North Dakota State University, Hettinger, ND (71)

NO ABSTRACT AVAILABLE

Influence of Cover Crops on Soil Microbial Activity and Degradation of S-Metolachlor.
Lucas Oliveira Ribeiro Maia*, William G. Johnson, Bryan G. Young, Joshua R. Widhalm, Eileen J. Kladivko, Shalamar Armstrong; Purdue University, West Lafayette, IN (72)

The use of cover crops is becoming increasingly popular among growers in the United States. Increased soil microbial activity following the use of cover crops has been documented and has the potential to alter the persistence of soil residual herbicides. Thus, two field experiments were conducted in 2019 through 2020 at Throckmorton and Pinney Purdue Agricultural Centers (TPAC and PPAC, respectively, to evaluate the influence of cover crop use on soil microbial activity and biodegradation of *S*-metolachlor. The cover crop species included in this study were cereal rye (*Secale cereale* L.) and crimson clover (*Trifolium incarnatum* L.). The three herbicide levels tested were, no residual, medium and heavy residual. Corn (*Zea mays* L.) was used as cash crop in the 2020 growing season. Cover crops were terminated 3 weeks before corn planting and biomass determined the day before termination. Soil samples were collected at 0 to 5 cm depth on the day before termination, 2, 4, 8, 12, and 16 weeks after termination (WAT). These samples were used to measure ß-glucosidase (BG) and dehydrogenase (DHA) activities. *S*-metolachlor concentration in the soil samples was determined from the samples collected from 3 to 8 WAT. ß-glucosidase activity was influenced by cover crop biomass, soil temperature, and soil organic matter content. On average, BG activity in treatments with cover crops was 2-fold greater at TPAC relative to PPAC. Averaged across cover crop treatments, S-MET concentration was reduced by 60 and 70% at TPAC and PPAC, respectively, between 3 and 4 WAT. No clear effect of S-MET on DHA activity was observed. The present study shows that the use of cover crops occasionally increases ß-glucosidase and dehydrogenase activities. Therefore, reduced persistence of S-MET may be expected when using cover crops. From an environmental standpoint, this represents lower risks of contamination. However, from a weed management perspective, this may raise some concerns.

Interaction Effects of Herbicide and Nitrogen Inhibitors on Nitrification and Weed Suppression in Corn. William H. Neels*[1], Amit J. Jhala[1], Javed Iqbal[1], Bijesh Maharjan[2], Laila Puntel[1], Richard Little[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Scottsbluff, NE (73)

Nitrogen is an essential nutrient for crop growth and development. Nitrogen is abundant in the atmosphere, although not in a plant-available form. Nitrogen management can be challenging due to the potential pathways for nutrient loss. Nitrogen undergoes several chemical reactions in the soil profile facilitated by ammonium-oxidizing bacteria (AOB). Nitrification is a chemical reaction conducted by *Nitrosomonas* and *Nitrobacter* populations to convert ammonium (NH_4^+) to nitrite (NO_2^-) and then to nitrate (NO_3^-). Nitrate is an anion, so it does not readily adsorb to negatively charged exchange sites in the soil. Nitrates can be leached during periods of heavy precipitation or irrigation. Nitrate leaching leads to lowered nitrogen use efficiencies and in turn economic inefficiencies. Nitrate leaching can also lead towards contamination of groundwater resources, which is a growing concern in Nebraska. Nitrification inhibitors temporarily reduce the abundance of AOB populations. Nitrapyrin and dicyandiamide are two commonly used active ingredients in nitrification inhibitor products. Herbicides can tend to generate non-target effects on soil microorganisms, including those involved in N reactions. Several studies have been conducted in laboratory settings to observe the effects of herbicide on nitrification and nitrate leaching. Evaluation of herbicide and nitrification inhibitor effect on nitrification in field corn (*Zea mays*) production is needed. Field experiments were conducted at the University of Nebraska-Lincoln South Central Agricultural Laboratory near Clay Center, Nebraska to evaluate the effects of herbicide and nitrification inhibitors on nitrification in silty loam soil. Treatments were laid out in a Split-plot factorial design with 4 replications. The main plot factor included 3 herbicide treatment levels: No application of pre-emergence herbicide, application of atrazine/bicyclopyrone/mesotrione/s-metolachlor premix, and application of acetochlor/mesotrione/clopyralid premix. The subplot factor included 5 fertilizer treatment levels: no application of nitrogen fertilizer, banded application of anhydrous ammonia with nitrapyrin nitrification inhibitor, banded application of anhydrous ammonia without a nitrification inhibitor, surface broadcast application of urea with dicyandiamide nitrification inhibitor, and surface broadcast application of urea without a nitrification inhibitor. Treatments were applied on April 23, 2020 on the same day crops were planted. Soil samples were taken weekly starting on May 6, 2020. Samples were taken at 0-10 and 10-20 cm sections. Samples for each plot were extracted and analyzed for nitrate and ammonium concentrations. Herbicide applications did not decrease nitrification at a significant level. Anhydrous ammonia with nitrapyrin decreased nitrification and retained ammonium concentrations significantly when compared to anhydrous ammonia applications without nitrapyrin at 14 DAT. Urea with dicyandiamide decreased nitrification and retained ammonium concentrations significantly when compared to urea applications without dicyandiamide at 21 DAT. Nitrogen treatments containing anhydrous retained ammonium concentrations at significantly higher levels when compared to urea treatments. There are future opportunities to recreate this study across multiple years with different weather patterns. Future research will include lab based studies to observe herbicide effect on nitrate leaching and nitrous oxide emissions.

Photosynthetic Response of Drought Tolerant Corn Hybrids to Water Stress and Weed Competition. Nash D. Hart*, Allyson M. Rumler, Erin E. Burns, Michigan State University, East Lansing, MI (74)

Water stress is a significant yield limiting factor in corn (*Zea mays*) production. Additionally, water stress exacerbates the impact of other stresses, both abiotic and biotic, to substantially decrease crop performance. Yield reductions caused by water stress results from suppressed photosynthesis and protein production. It is essential for crops to be able to withstand water stress and maintain elevated levels of productivity. With the expected change in precipitation throughout the Great Lakes Region, a field study was conducted in East Lansing, Michigan in 2019- 2020 to evaluate the impacts of weed competition and water stress on drought tolerant corn hybrids. The study followed a completely randomized design with four replications. Factorial treatment combinations consisted of hybrid (DKC47-27 DroughtGard® Double Pro® (DT) or DKC46-20 Triple Pro (DS)), weed pressure (weed free-W1, 50% control-W2, or no control-W3), and precipitation (ambient or reduced). Rainout shelters were designed to intercept approximately 70% of ambient rainfall. Corn photosynthesis was measured on five plants per plot. Measurements were taken at two growth stages known to be sensitive to water stress (V4/V6 and R3/R4). Photosynthetic measurements were taken with a MultispeQ measuring four parameters: quantum yield of photosystem II (Phi2), quantum yield of non-photochemical quenching (PhiNPQ), quantum yield of other unregulated losses (PhiNO), and relative chlorophyll (RC). Data were analyzed using linear mixed effect models in R and means were separated using Tukey's HSD. 2019 and 2020 data were not significantly different and therefore analyzed together. When Phi2 was measured at R3/R4 there was a significant interaction between hybrid and weed pressure (p=0.05). DT hybrids under W3 had an 11% decrease in Phi2 compared to DT hybrids under W1; however, there was no difference between DS hybrids across weed pressures. When PhiNPQ was measured at R3/R4, there was a significant interaction between hybrid and weed pressure (p=0.04), where DT hybrids under W3 had 17% greater PhiNPQ compared to DT hybrids under W1. At R3/R4, there was a significant three-way interaction of hybrid, precipitation, and weed pressure for PhiNO (p=0.06). Under reduced precipitation, DS hybrids under W3 had 8% greater PhiNO compared to DS hybrids under W1. In addition, DT hybrids with full precipitation had 10% greater PhiNO compared to DT hybrids under reduced precipitation and W3. At R3/R4, RC had a significant interaction between hybrid and precipitation (p=0.01). DT hybrids with reduced precipitation had 8% less RC than DT hybrids with ambient precipitation; there was no difference in DS hybrids. RC was the only photosynthetic parameter that was significant at V4/V6 with a significant interaction between hybrid, weed, and precipitation (p=0.08). Under reduced precipitation DT hybrids under W3 had 10% greater RC compared to W1 DT hybrids. In addition, under reduced precipitation DS hybrids under W3 had 8% less RC compared to W1 DS hybrids. During early vegetative growth stages, weeds had a negative impact on RC, but in reproductive growth stages weeds did not have an effect on RC. In conclusion, photosynthesis of DT hybrids is impacted more by weed pressure than DS hybrids.

Antagonism of ACCase Inhibitor Herbicides Used for Control of Volunteer Corn in Enlist E3 Soybean Systems. Marcelo Zimmer*, Bryan G. Young, William G. Johnson; Purdue University, West Lafayette, IN (75)

Volunteer corn 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 poor setup/operation of combines. Herbicide options for control of volunteer corn in soybean fields depend on the herbicide-tolerance traits of the corn hybrid planted during the previous growing season. Many farmers utilize corn hybrids with stacked resistance to both glyphosate and glufosinate, limiting herbicide choices for postemergence volunteer corn control to the application of ACCase inhibitor herbicides such as clethodim and quizalofop. Synthetic auxin herbicides such as 2,4-D and dicamba are known to antagonize the efficacy of ACCase inhibitor herbicides when used in tank-mixtures. The widespread adoption of Enlist soybeans across many regions of the United States may result in increased instances of failed ACCase herbicide applications. Research also indicates that glyphosate and glufosinate may reduce the efficacy of ACCase-inhibiting herbicides on glyphosate- and glufosinate-tolerant corn. Field experiments were conducted to evaluate the effect of 2,4-D (1065 g ae ha^{-1}) glyphosate (1260 g ai ha^{-1}), and glufosinate (595 g ai ha^{-1}) on the efficacy of different rates of clethodim (70 and 105 g ai ha^{-1}) and quizalofop (31 and 46.3 g ai ha^{-1}) for control of volunteer corn in 2,4-D tolerant soybeans. Three F1 corn hybrids with different herbicide-tolerance traits (Non-GMO, SmartStax, and Enlist) were planted across the plots to simulate volunteer corn infestation. The addition of 2,4-D to clethodim reduced RR2/LL corn control by 11% at the low rate, which is the rate of clethodim traditionally used when the activity of clethodim is not compromised. In addition, 2,4-D reduced RR2/LL corn control with quizalofop by 92 and 95% at the low and high rate of quizalofop, respectively. Glyphosate and glufosinate did not appear to affect RR2/LL corn control with clethodim or quizalofop. Increasing clethodim rates by 50% resulted in increased RR2/LL corn control. Quizalofop rates higher than the rates tested in this experiment may be necessary for control of volunteer corn in 2,4-D tolerant soybean systems where 2,4-D is applied. Split herbicide applications and improved adjuvant use could be other alternatives for overcoming antagonism.

Waterhemp Management in Southern Wisconsin Using a Layered Residual Approach in Glufosinate-Resistant Soybeans. Daniel H. Smith*, Nicholas J. Arneson, Ryan P. DeWerff, Maxwel Coura Oliveira, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (76)

Waterhemp (*Amaranthus tuberculatus* (Moq.) J. D. Sauer) is a troublesome weed species in soybean production across the US North Central region. Multiple site-of-action resistance, rapid growth rate, and limited postemergence (POST) control options have resulted in increased reliance on preemergence (PRE) herbicides for waterhemp control. The objective of this study was to investigate the efficacy of using layered applications of residual herbicides in glufosinate-resistant soybeans for waterhemp control. Soybean studies were established near Lancaster, WI (2019: Silt loam soil, pH=7.5 and 2.6% OM; 2020: Silt loam soil, pH=7.3 and 2.4% OM) and near Brooklyn, WI (silt loam, pH=7.1, and 2% OM) in the spring of 2019 and 2020 in a RCBD with four replications (3 x 7.6 m plot size). Trials at Lancaster followed corn and were chisel-plowed and spring cultivated prior to establishment. Trials at Brooklyn followed soybean and were field cultivated in spring prior to establishment. Soybeans were planted June 4 2019 (variety: CZ 2069LLGT) and May 20 2020 (variety: CZ 2550GTLL) at Lancaster, and May 5 2019 (variety: OS-2519LLGT27) and May 22 2020 (variety: NK S20-J5E) at Brooklyn (385,000 seeds ha^{-1}). A blanket PRE application of sulfentrazone + metribuzin (151 and 207 g ha^{-1}) was applied to the trial area within three days of planting with a tractor mounted sprayer delivering 132 L ha^{-1} of spray solution using TTI11002 flat-fan nozzles. POST herbicide treatments consisted of glufosinate and glufosinate plus 6 treatments including commonly used group 2, 14, and 15 site-of-action herbicides. Herbicide treatments included: group 2: imazethapyr, group 14: fomesafen, and group 15: acetochlor, dimethenamid-P, pyroxasulfone, and *S*-metolachlor. Two commercial premix products were also evaluated in combination with glufosinate: fomesafen + S-metolachlor and fomesafen + acetochlor. Herbicide rates were based on soil characteristics and label requirements. POST herbicides were applied when soybeans reached the V2-V3 growth stages with a CO_2 -pressurized backpack sprayer delivering 140 L ha^{-1} of spray solution using at Lancaster (2019: XRFF11002, 2020: TT110015) and at Brooklyn (2019: AIXR110015, 2020: TT110015) nozzles. At ~14 and ~28 days after treatment (DAT) visual herbicide efficacy data were collected. Grain yield was determined by harvesting the center two rows of all plots an Almano plot combine. Yields were standardized to 13% moisture. 2019 grain yield at Lancaster was not collected due to flooding. Data were analyzed using R (version 3.6.1) statistical software. ANOVA was performed for waterhemp control (%) and grain yield; herbicide treatments and site-year were treated as fixed effects whereas replication were treated as random effect. All herbicide treatments provided > 90% control of waterhemp at 14 DAT. At 28 DAT, the following herbicide treatments + glufosinate provided >90% control: fomesafen, fomesafen + *S*-metolachlor, fomesafen + acetochlor, acetochlor. Yields within each site-year were not different (P>0.05). Fomesafen, when combined with a group 15 herbicide and glufosinate, enhanced burndown and residual control of waterhemp. This trial showcases the value layered residual herbicides in a glufosinate-resistant soybean system for waterhemp control.

Soybean Symptomology and Yield Response to Sub-Labeled Doses of 2,4-D and Dicamba as Influenced by Varieties. Jesaelen Gizotti de Moraes*, Vitor M. Muller Anunciato, Jeffrey A. Golus, Kasey P. Schroeder, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (77)

Purported soybean injury due to unintended off-target movement of dicamba and 2,4-D has raised concerns. The objective of this research was to investigate the symptomology and consequent impact on yield caused by exposition of plants to sub-labeled doses of two auxin herbicides (2,4-D and dicamba) on the several commonly used soybean varieties in Nebraska. Field experiments were conducted in 2019 and 2020 in North Platte and Gothenburg, NE, as a randomized complete block design with four replications using seven soybean varieties (Hoegemeyer 2511NRR, Hoegemeyer 2811NR, Asgrow 2636, Pioneer P27T59R, Pioneer P22T41R2, Syngenta S26-F4L, and CZ2312LL), and five doses of dicamba (0.0056, 0.056, 0.56, 5.6, and 56 g ae ha^{-1}), and five doses of 2,4-D (0.01065, 0.1065, 1.065, 10.65, 106.5 g ae ha^{-1}) applied as late POST (~R1). Plots were 1.5-m wide by 9.0-m long, using two, 76-cm spaced rows. Herbicide treatments were applied using a plot sprayer equipped with 10 independently spray booms calibrated to deliver a spray volume of 140 L ha^{-1} at 276 kPa at 1.75 m s^{-1} (TTT11003 nozzle). A control plot (no herbicide) was included for a total of 77 treatments and extra soybean rows were used as border to prevent contamination from adjacent plots. Plots were kept weed free from planting to harvest. Visual estimation of injury and plant heights were collected at 14 and 28 d after treatment (DAT). Number of pods per plant, number of seeds per pod, 100 seed weight, and total seed mass were recorded for six plants from each plot at harvest, as well as soybean grain yield. Data were subjected to ANOVA and dose-response curves were fitted to the data using the log-logistic function of the dr4pl package in R 3.4.2. Overall, slight differences could be observed among soybean varieties but results within herbicide and dose were similar. Drastically yield reduction was observed when plants were exposed to the highest dose of dicamba suggesting that soybean plants are more sensitive to dicamba than to 2,4-D. However, this trend is buffered as the dose is reduced. Slight increase in yield was observed when plants were exposed to the lowest doses of either dicamba or 2,4-D herbicides but results were herbicide and variety-specific. Symptomology must be carefully interpreted and may not be an accurate predictor for yield.

Interaction of 2,4-D Applied in Combination with Glyphosate or Graminicides on Grass Weed Control in Enlist E3® Soybeans. Rui Liu*[1], Isaac N. Effertz[2], Taylor Lambert[1], Amit J. Jhala[3], Prashant Jha[4], Vipan Kumar[1]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Manhattan, KS, [3]University of Nebraska-Lincoln, Lincoln, NE, [4]Iowa State University, Ames, IA (78)

Recent introduction of Enlist E3® soybean allows growers to use POST applications of 2,4-D for in-season weed control, especially for controlling glyphosate-resistant weeds. The POST applications of 2,4-D can be tank-mixed with glyphosate or graminicides for both grassy and broadleaf weed control. However, grass weed control can be compromised, as tank-mixing 2,4-D may antagonize the efficacy of glyphosate or graminicides. The main objective of this research was to determine the effectiveness of 2,4-D in combination with glyphosate, clethodim, or quizalofop p-ethyl on grass weed control in Enlist E3® soybean. Field studies were conducted in 2020 growing season at Kansas State University Agricultural Research Center near Hays, Kansas (KSU-ARCH) and University of Nebraska near Lincoln, Nebraska (UNL). An Enlist E3® soybean variety "P30T92E" was planted on May 11 at the UNL site and on May 20 at the KSU-ARCH site. Giant foxtail (*Setaria faberi*), hairy cupgrass (*Eriochloa villosa*), and fall panicum (*Panicum dichotomiflorum*) were major grassy weeds at the UNL site. Southwest cupgrass (*Eriochloa acuminata*) and green foxtail (*Setaria viridis*) were the dominant grassy weeds at KSU-ARC site. Herbicide treatments, including clethodim, quizalofop-p-ethyl, and glyphosate applied at V3-V4 soybean alone or in combination with 2,4-D and sequential treatments of 2,4-D followed by (separated by 5 days) clethodim, quizalofop-p-ethyl or glyphosate and vice-versa were tested. All treatments were arranged in a randomized complete block design with 3 to 4 replications. Data on visible control (%) of each grass weed species were recorded at 14, 28 and 54 days after treatment (DAT). The aboveground shoot dry biomass of grassy weeds and soybean grain yields (kg ha^{-1}) were determined. Results indicated that addition of 2,4-D to clethodim or quizalofop-p-ethyl tank-mixtures or applied in sequential treatments at 5 days after the application of graminicides reduced control of giant foxtail (69 to 79%), hairy cupgrass (70 to 79%), and fall panicum (69 to 79%) at 28 DAT compared to the standalone treatments of graminicides (93 to 97%) at the UNL site. Control of all three grass species was moderate (69 to 76%) with glyphosate alone or in tank-mixture with 2,4-D. However, an addition of glyphosate to tank-mixtures of 2,4-D with clethodim or quizalofop improved the efficacy on all three grass species. Soybean grain yield ranged from 2336 and 3707 kg ha^{-1} for majority of the treatments. At KSU-ARCH site, the highest control (87 to 90%) of southwest cupgrass and green foxtail was observed with sequential treatment of 2,4-D at 5 days prior to the application of quizalofop-p-ethyl. Control of both grass species did not exceed 78% with rest of the treatments at 28 DAT. Soybean grain yield ranged from 500 to 1066 kg ha^{-1}. Overall, these preliminary results suggest that addition of 2,4-D with clethodim or quizalofop-p-ethyl can compromise efficacy of graminicides and glyphosate should be added in these mixtures to optimize grass control in Enlist E3® soybean.

Integrative Analysis of Soybean Weed Management in Kansas. Tyler P. Meyeres*, Dallas E. Peterson, Sarah Lancaster; Kansas State University, Manhattan, KS (79)

Integrative analysis is the analysis of multiple data sets pooled into one. An integrative analysis (IA) is different than a meta-analysis (MA) because a MA utilizes summary statistics, while an IA utilizes raw data. The main advantage of IA over MA is the ability to create larger data sets, which increases power. The main objective of this IA was to analyze a multi-year data set to summarize the effect of number of applications and number of herbicide active ingredients (AI) included in each treatment on weed control in soybeans (*Glycine max*) herbicide evaluation trials. Trials consisted of data collected by Dr. Dallas Peterson during 2018 and 2019. Trials were omitted if there were missing planting dates, missing soybean traits, missing application dates, unknow herbicide AI, or the trial compared something other than herbicide treatments. Trials were also omitted if only one herbicide application timing was being compared. All data were analyzed using R. Thirty-one trials were analyzed with 1,061 observations, six soybean herbicide resistance traits, ten herbicide groups, and 27 AI utilized. The main weed species evaluated were *Ipomoea hederacea* (ivyleaf morningglory), *Amaranthus palmeri* (Palmer amaranth), and *Abutilon theophrasti* (velvetleaf). Glyphosate- and dicamba-resistant soybeans comprised more than 60% of the soybeans planted. As number of passes increased, weed control increased, regardless of weed species. Treatments with two or more passes resulted in greater than 90% control. Treatments with a single AI, resulted in 39 to 45% control. As the number of herbicides treatment^{-1} increased, weed control generally increased, regardless of weed species. Treatments with two AI's resulted in 73 to 79% control and treatments with three AI's resulted in 84 to 90% control. Treatments with four, five, and six AI's resulted in greater than 90% control and treatments with seven AI's resulted in 71 to 78% control. Results of this analysis support recommendations that more than one herbicide application should occur during the growing season. To prevent early season competition, one of the applications should occur prior to crop and weed emergence and subsequent applications should occur soon after crop and weed emergence. Herbicide treatments should include at least two AI's for maximum efficacy. With the addition of more data, the results of this analysis could improve the understanding of the most effective weed management programs to control and mitigate the spread of herbicide resistant weeds.

Interaction of Dicamba Applied in Combination with Glyphosate or Graminicides on Grass Weed Control in Roundup Ready 2 Xtend® Soybeans. Rui Liu*[1], Isaac N. Effertz[2], Taylor Lambert[1], Amit J. Jhala[3], Prashant Jha[4], Vipan Kumar[1]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Manhattan, KS, [3]University of Nebraska-Lincoln, Lincoln, NE, [4]Iowa State University, Ames, IA (80)

Introduction of glyphosate/dicamba-resistant (GDR) soybean has allowed POST applications of dicamba for in-season weed control. These POST dicamba applications are generally tank-mixed with glyphosate or graminicides for both grassy and broadleaf weed control. Anecdotal evidence suggests that grass weed control may be problematic in GDR soybean, as tank-mixing dicamba may antagonize efficacy of glyphosate or graminicides. The main objective of this research was to determine the effectiveness of tank-mixtures of dicamba in combination with glyphosate, clethodim, or quizalofop-p-ethyl on grass weed control in GDR soybean. Field studies were conducted at Kansas State University Agricultural Research Center near Hays, Kansas (KSU-ARCH) and University of Nebraska near Lincoln, Nebraska (UNL) in 2020 growing season. “A GDR soybean variety “AG34X7” was planted at 387,543 seeds ha^{-1} on May 20 at the KSU-ARCH site, whereas a GDR soybean variety NK S29-K3X” was planted at 345,800 seeds ha^{-1} on May 11 at the UNL site. Southwest cupgrass (*Eriochloa acuminata*) and green foxtail (*Setaria viridis*) were the dominant grassy weeds at KSU-ARC site. In contrast, giant foxtail (*Setaria faberi*), hairy cupgrass (*Eriochloa villosa*), and fall panicum (*Panicum dichotomiflorum*) were major grassy weeds at the UNL site. Herbicide treatments, including clethodim, quizalofop-p-ethyl, and glyphosate applied as early POST (V3-V4 soybean) alone or in combination with dicamba and sequential treatments of dicamba followed by (separated by 5 days) clethodim, quizalofop-p-ethyl or glyphosate and vice-versa were tested. All treatments were arranged in a randomized complete block design with 3 to 4 replications. Data on percent visible control of each grass weed species were recorded at 14, 28 and 54 days after treatment (DAT). The aboveground shoot dry biomass of grassy weeds and soybean grain yields (kg ha^{-1}) were determined at soybean maturity. Results indicated that control of both southwest cupgrass and green foxtail was lower at KSU-ARCH site and did not exceed 71% with majority of the treatments. Glyphosate applied alone and in sequential treatments at 5 days prior or after dicamba applications provided =85% control of both grass species. The highest soybean yield (900 to 1127 kg ha^{-1}) was observed with glyphosate alone or in tank-mixtures with clethodim, quizalofop-p-ethyl and/or dicamba. In contrast, tank-mixing dicamba to clethodim or quizalofop p-ethyl or dicamba applied 5 days prior to the application of graminicides reduced giant foxtail (64-82%), hairy cupgrass (71- 82%), and fall panicum (72- 88%) at the UNL site. Addition of glyphosate to tank-mixtures of dicamba with clethodim or quizalofop restored the efficacy of both graminicides on all three grass species. Soybean grain yield (4322 to 5190 kg ha^{-1}) did not differ for majority of the treatments. In conclusion, these results suggest that addition of dicamba with clethodim or quizalofop-p-ethyl can compromise efficacy of graminicides, and glyphosate should be added in these mixtures to optimize grass control in GDR soybean.

Assessment of Soybean (*Glycine max*) Tolerance to Pre-emergence Exposure of Trifludimoxazin, and Other PPO-Inhibiting Herbicides in a Hydroponic System. Nicholas R. Steppig*[1], Samuel D. Willingham[2], Douglas A. Findley[2], Bryan G. Young[3]; [1]Purdue University, West Lafayette, IN, [2]BASF Corporation, Research Triangle Park, NC, [3]Purdue University, Brookston, IN (81)

Trifludimoxazin is a new PPO-inhibiting herbicide currently being developed for preplant applications, both alone and in combination with saflufenacil, in soybean. Previous research has demonstrated that preplant applications of 25 g ai ha^{-1} trifludimoxazin alone resulted in <10% injury to soybean. The addition of saflufenacil to trifludimoxazin at a 2:1 ratio increased the risk for soybean injury, and a differential response was observed across soybean varieties under field conditions. A hydroponic bioassay was conducted to investigate the effect of soybean exposure to trifludimoxazin, saflufenacil, and the combination of the two herbicides. Experiments were conducted utilizing a 3-factor factorial, randomized complete block design with 6 replications. Factors included herbicide (trifludimoxazin, saflufenacil, and trifludimoxazin plus saflufenacil), herbicide rate (based on preliminary data), and soybean variety. The soybean varieties included two varieties with putative sensitivity to saflufenacil (AG39X7 and P39A58X) and two varieties with putative tolerance to saflufenacil (HS39X70 and P63A47X). Soybean were inserted into culture tubes containing rate titrations of each herbicide once hypocotyls measured 4cm in length, then placed in a growth chamber set to 25C, 60% relative humidity, and cycles of 8hr darkness followed by 16hr of light at 700µmol m^2 s^{-1} for five days. Visual assessments of soybean injury were collected five days after transfer, and the herbicide rate required to cause 50% injury (GR_{50} value) was calculated using log-logistic regression models using the *drc* package in R. Interactions between the combination of trifludimoxazin and saflufenacil were assessed using an adapted Isobole method comparing the predicted independent activity of each herbicide versus the observed activity of the combination. Varietal differences were not observed following soybean exposure to trifludimoxazin. Soybean injury following exposure to saflufenacil differed by variety, where GR_{50} values ranged from 7.1 to 11 ppb for the putative sensitive varieties, compared to 24 to 38 ppb for the putative tolerant varieties. A similar trend of varietal sensitivity was observed following exposure to the combinations of trifludimoxazin and saflufenacil, where GR_{50} values for putative sensitive varieties ranged from 6.6 to 8.0 ppb, versus 17 to 25 ppb for the putative tolerant varieties. Interaction assessments indicated the combination of trifludimoxazin plus saflufenacil was additive (i.e. neither antagonistic nor synergistic) for all varieties evaluated. These results imply that field observations of varietal differences following soybean exposure to trifludimoxazin plus saflufenacil were likely a result of differential tolerance to saflufenacil. The additive interaction following exposure to a combination of both herbicides may present an increased risk of injury compared to either herbicide used independently, but this increased risk may be mitigated by use of soybean varieties with tolerance to saflufenacil.

Effects of Cereal Rye Seeding Rate on Soybean Growth and Early-season Emergence of Waterhemp and Foxtail Species. Jacob E. Vaughn*, Brian Dintelmann, Eric G. Oseland, Mandy Bish, Kevin W. Bradley; University of Missouri, Columbia, MO (82)

Herbicide resistance weeds, particularly waterhemp [*Amaranthus tuberculatus* (Moq.) J.D. Sauer], have resulted in the necessity for a more integrated approach to weed management in U,S. soybean production systems. Cereal rye (*Secale cereale* L.) as a winter cover crop has been shown to effectively suppress early-season weed emergence in soybean, including suppression of waterhemp. One challenge of applying the results from published research is that cover crop seeding rates utilized in these studies may differ from seeding rates utilized by producers. An experiment was conducted in 2018, 2019, and 2020 near Columbia, Missouri to determine waterhemp suppression and soybean growth across multiple cereal rye seeding rates (0, 34, 56, 79, 110, and 123 kg ha^{-1}) when soybean was planted into non-terminated, living cereal rye. Results indicate that as cereal rye seeding rate increased from 0 to 123 kg ha^{-1}, waterhemp control increased from 1 to 60% by 28 days after planting (DAP). Additionally, as cereal rye seeding rate increased, waterhemp emergence decreased. Waterhemp control was optimized at seeding rates of 56 kg ha^{-1} or higher. Soybean yield ranged from 3211 to 3417 kg ha^{-1} for all cereal rye seeding rates, while the no cereal rye control reduced soybean yield to 2639 kg ha^{-1} due to inadequate weed suppression. No adverse effects to soybean stand count were observed at any of the cereal rye seeding rates relative to treatments that lacked cereal rye cover. Results from this study indicate that seeding rates of 56 kg ha^{-1} or higher provided waterhemp suppression without negative impacts to soybean stand or yield.

Utilization of Residual Herbicides in 2,4-D Tolerant Soybean Production. Jon Scott*[1], Ivan B. Cuvaca[1], Stevan Knezevic[2]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Concord, NE (83)

Continued weed resistance to herbicides in the Midwest, introduction of 2,4-D tolerant soybean could provide another option for weed control. Also important in weed resistant management is the use of residual herbicides and the timing of the residual herbicide application. Herbicide programs were initiated at the Agronomy Research Farm in Mead, NE in 2,4-D tolerant soybean using PRE only, Early POST at 2T only, PRE followed by POST, and PRE followed by a POST containing residual activity. A graminicide was applied at 1T on all treatments including the check to control volunteer corn and this also removed the first flush of grass species. POST treatments were applied at 6T. Excellent rainfall for activation, in-season irrigation, and control of volunteer corn helped the PRE only treatments exceed expectations with only a few ABUTH escapes. Enlist DUO applied Early POST did have SETVI and AMATA escapes, however yield was protected. Addition of residual products aided in broadleaf control only. 27 DAT of the POST application with no residual, excellent control of SETVI, ABUTH and AMATA was observed in all but on treatment and yield was secured. The addition of POST residual products did aid in complete weed control. Note that in some programs up to 6 sites of action were used. No regrowth or new populations were observed at the end of season ratings. Yields were similar between treatments (64-70 bu A^{-1}) while the Nontreated check yielded 57 bu A^{-1}. (SETVI was controlled in the check when volunteer corn was sprayed) The 2,4-D tolerant soybeans should be used in conjunction with additional modes of actions and as part of an Integrated Weed Management Program.

Glyphosate-Tolerant Soybean Response to 2,4-D Micro Rates. Ivan B. Cuvaca*[1], Jon Scott[1], Stevan Knezevic[2]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Concord, NE (84)

Widespread resistance to glyphosate has rendered the herbicide ineffective on several populations of weeds, particularly in glyphosate-tolerant (GT) crops. In response, new approaches to managing resistant biotypes such as the Enlist™ system have been developed. This system involves genetic modifications to corn and soybean that allow in-crop use of glyphosate and 2,4-D. To understand the impact of 2,4-D drift on GT soybean, a study using a randomized complete block design with six replications and a split-plot arrangement of treatments was conducted in 2019 near Concord, NE and 2020 at Mead, NE. Main plots consisted of three 2,4-D application times [second trifoliate (V2); beginning of flowering (R1); and full flowering (R2)] and subplots consisted of six micro rates of 2,4-D (1/5; 1/10; 1/50; 1/100; 1/500; and 1/1000 of the label recommended dose of 1,120 g ae ha^{-1}) to simulate 2,4-D drift and a check with no herbicide applied. Soybean injury was visually assessed at 7, 14 and 21 d after treatment; days to canopy closure was recorded; and yield loss was estimated following harvesting. In general, there was an increase in soybean injury and delay in canopy closure with increase in micro-rates of 2,4-D which ultimately resulted in yield losses. Based on estimates of the effective dose of 2,4-D required to cause 5% (0.23 Mg ha^{-1}) yield loss, GT soybean was a 2.5- and 2-times more sensitive to 2,4-D at R1 (37.68 g ae ha^{-1}) than V2 (95.08 g ae ha^{-1}) and R2 (75.50 g ae ha^{-1}) stage, respectively. Therefore, 2,4-D drift onto GT soybean should be prevented especially at R1.

Effect of Soybean Chaff on Emergence Patterns of Waterhemp, Velvetleaf, and Giant Foxtail. Avery J. Bennett*, Prashant Jha, Ramawatar Yadav, Alexis L. Meadows, Edwards Dearden, Ryan C. Hamberg; Iowa State University, Ames, IA (85)

Weeds have been a constant threat to sustainable crop production around the world. However, this threat has become more critical recently in the U.S. soybean production due to the evolution of multiple herbicide-resistant (HR) weed populations and dwindling herbicide resources for weed control. Therefore, there is an urgent need to incorporate non-chemical weed control tactics such as harvest weed seed control (HWSC) that aids in reducing weed seed inputs to the soil seed bank. Chaff-lining is one of the most inexpensive HWSC method widely adopted in Australia to combat HR weeds. The objective of this research conducted in 2020 at the Iowa State University Agronomy greenhouse in Ames, Iowa was to determine the effect of soybean chaff on emergence patterns of waterhemp [*Amaranthus tuberculatus* [(Moq.) J. D. Sauer], velvetleaf (*Abutilon theophrasti* Medik.), and giant foxtail (*Setaria faberi* Herrm.). Four soybean chaff treatments (no chaff, chaff at 396, 496, 594 kg ha^{-1}) were selected to represent different soybean yield potentials (2690, 3362, 4035 kg ha^{-1}) in the Midwest. The experiment was conducted in a randomized complete block design (RCBD) with four replications and repeated in time. Emerged seedlings were counted and removed (without disturbing the chaff) at 3-day interval for 6 weeks after planting (WAP). Percent emergence of waterhemp, velvetleaf, and giant foxtail was recorded. Data were analyzed in *R* using a three-parameter log-logistic model, fitted using a “time-event model”. Results indicated a significant reduction in percent cumulative emergence of the three weed species with an increase in the amount of soybean chaff [0 (no chaff) to 594 kg ha^{-1}]. Soybean chaff of 396 kg ha^{-1} which is equivalent to 2,690 kg ha^{-1} grain yield, reduced emergence of waterhemp by =80%, velvetleaf by =30%, and giant foxtail by =15%, compared with no-chaff at 6 WAP. Chaff of 594 kg ha^{-1} which is equivalent to 4035 kg ha^{-1} grain (average yield of soybean in Iowa), reduced emergence of waterhemp by =95%, and velvetleaf and giant foxtail by =55%, compared with no-chaff at 6 WAP. It took only 236 kg ha^{-1} (ED_{50} value) of soybean chaff to reduce waterhemp emergence by 50%; however, it took =550 kg ha^{-1}(ED_{50} values) for velvetleaf and giant foxtail. These results suggest that chaff lining at soybean harvest can potentially be utilized to reduce the emergence of waterhemp, velvetleaf, and giant foxtail and potential spread of herbicide resistance. Overall, this study demonstrates that the HWSC method of chaff lining offers a great opportunity for U.S. soybean growers to manage HR weed seed banks.

Dicamba-Tolerant Soybean Response to 2,4-D Micro Rates. Stevan Knezevic*[1], Jon Scott[2], Ivan B. Cuvaca[2]; [1]University of Nebraska-Lincoln, Concord, NE, [2]University of Nebraska-Lincoln, Lincoln, NE (86)

Dicamba-tolerant (DT) soybean has been available to farmers for several years. More recently, however, 2,4-D-tolerant soybean was launched. Like dicamba, 2,4-D is typically associated with increased risk for drift and has been implicated in damage to non-target crops including non-2,4-D tolerant crops. Field studies were conducted near Concord, NE in 2019 and at Mead, NE in 2020 to investigate DT soybean response to 2,4-D micro-rates at three growth stages. The experiments were laid using a randomized complete block design with six replications and a split-plot arrangement of treatments. Main plots consisted of three 2,4-D application times [second trifoliate (V2); beginning of flowering (V7/R1); and full flowering (R2)] and subplots consisted of six micro rates of 2,4-D (1/5; 1/10; 1/50; 1/100; 1/500; and 1/1000 of the label recommended dose of 1,120 g ae ha^{-1}) and a check with no herbicide applied. Soybean injury assessment was performed at 7, 14 and 21 d after treatment; number of days to canopy closure was recorded; and yield loss was estimated following harvesting. Results showed an increase in DT soybean injury, delay in canopy closure and reduction in yield with increase in 2,4-D dose regardless of application time. Of all growth stages, R1 was the most sensitive to 2,4-D based on estimates of the effective dose (ED) of the herbicide required to cause 5, 10 or 20% visual injury, delay in canopy closure as well as yield loss in DT soybean. For example, 2,4-D doses required to cause 5% visual injury, delay in canopy closure (2.3 d), and yield loss (0.23 Mg ha^{-1}) in DT soybean were 24.01, 13.14 and 8.66 g ae ha^{-1} at R1; 25.99, 41.99 and 18.34 g ae ha^{-1} at V2; and 27.76, 10.94 and 11.65 g ae ha^{-1} at R2, respectively. Altogether, these results show that DT soybean is sensitive to 2,4-D especially at R1.

Herbicide Programs for Weed Control in Isoxaflutole-Resistant Soybean. Vipan Kumar*[1], Isaac N. Effertz[2], Taylor Lambert[1], Rui Liu[1]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Manhattan, KS (87)

The widespread evolution of herbicide-resistant (HR) weeds pose a serious management concern for soybean producers in the Midwestern United States, including Kansas. Recent commercialization of isoxaflutole-resistant (Liberty Link® GT27™) soybean will provide growers a new herbicide site of action (SOA) for weed control in soybean. The main objectives of this research were to (1) determine the effectiveness of PRE applied isoxaflutole alone or in various tank mixtures (one-pass) or followed by (*fb*) an early POST (EPOST) treatment of glyphosate plus glufosinate mixture (two-pass) for weed control, and (2) determine the ultimate impact of these programs on grain yields of isoxaflutole-resistant soybean in no-till dryland environment. Field study was conducted in 2020 growing season at Kansas State University Agricultural Research Center (KSU-ARC) near Hays, KS. A Liberty Link® GT27™ soybean variety 'CZ 3480GTLL' was planted at 387,543 seeds ha^{-1} on May 20. The study was established in no-till wheat stubble and had a natural infestation of Palmer amaranth (*Amaranthus palmeri*) and stinkgrass (*Eragrostis cilianensis*). Fourteen different herbicide programs, including PRE applied isoxaflutole alone or in various tank-mixtures or *fb* a POST treatment of glyphosate plus glufosinate were evaluated. The POST treatment was a mixture of glyphosate at 1260 g ha^{-1} and isoxaflutole (Alite™ 27) at 655 g ha^{-1}. Treatments were arranged in a randomized complete block design, with four replications. Data on percent visible control of each weed species were recorded at biweekly interval throughout the growing season. Total weed biomass and soybean grain yields (kg ha^{-1}) were determined at soybean harvest. Results indicated that a single PRE application of isoxaflutole in combination with s-metolachlor + fomesafen, pyroxasulfone, sulfentrazone + cloransulam-methyl, metribuzin, pyroxasulfone + metribuzin, and flumioxazin + pyroxasulfone provided 82 to 99% control of Palmer amaranth and =97% control of stink grass at 15 weeks after PRE (WAPRE). End-season control of Palmer amaranth did not exceed 49% with a single PRE alone treatment of isoxaflutole. All PRE *fb* POST treatments had excellent, season-long control of Palmer amaranth (93 to 99%) and stink grass (98 to 100%). Consistent with percent visible control, total weed biomass at soybean harvest was reduced by ³ 94% with all PRE *fb* POST treatments. However, PRE applied isoxaflutole alone or in combination with s-metolachlor + fomesafen, and sulfentrazone + cloransulam-methyl reduced total weed biomass by 62 to 84%. Soybean grain yield did not differ for majority of the treatments and ranged from 1052 to 1558 kg ha^{-1}. In conclusion, these results suggest that the PRE *fb* POST (two pass) herbicide programs (with multiple sites of actions) can be utilized for season-long weed control in Liberty Link® GT27™ soybean.

The Effect of Cereal Rye Cover Crop with Various Rates and Application Timings of Acetochlor on Common Waterhemp Control. Alexander R. Mueth*, Madison R. Decker, Karla L. Gage; Southern Illinois University, Carbondale, IL (88)

Herbicide-resistant weeds are a major problem across the globe in multiple cropping systems, including soybean (*Glycine max* (L.) Merr.). Season long weed control has become much more costly and time consuming due to this and the levels of control are not as great as they used to be. This has forced a shift in weed science research looking for new and improved ways of suppressing driver weeds with various methods outside chemical control. There is a great deal of literature being published recently detailing the positive effects of early season weed control seen from cereal rye (*Secale cereale* L.) cover crops (Baraibar, et al., 2017). However, the interactions between existing preemergent herbicides and these cover crops and the residues they leave behind is lesser known. Acetochlor, (Group 15) is one of the more widely used preemergent herbicides used by Illinois soybean growers to provide residual waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer) control. Therefore, the objective of this study is to evaluate acetochlor in a cereal rye cover crop applied at three rates and three timings in standing rye and bare ground plots for early season suppression of common waterhemp.

Identification of Soybean Lines with Differential Sensitivity to Dicamba. Matthew Osterholt*[1], Scott McAdam[1], Katy Rainey[2], Caio Canella Vieira[3], Pengyin Chen[3], Bryan G. Young[4]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, W. Lafayette, IN, [3]University of Missouri– Fisher Delta Research Center, Portageville, MO, [4]Purdue University, Brookston, IN (89)

In 2019, over 90% of the dicamba related drift events in Indiana involved off-target movement to dicamba-sensitive soybean (*Glycine max* (L.) Merr.). Research conducted at the University of Missouri – Delta Center Soybean Breeding program in 2019 evaluated 230 soybean lines and identified several lines that were less sensitive to dicamba than other soybean lines. Identifying soybean lines that have decreased sensitivity to dicamba could offer a unique opportunity to develop soybeans varieties that can minimize the impacts of off-target dicamba movement and further elucidate the mode of action for dicamba. As a result, a field experiment was conducted in 2020 to 1) validate the phenotypic differences between soybean lines that purportedly have differential sensitivity to dicamba, and 2) quantify abscisic acid (ABA) concentrations in dicamba-treated leaf tissue as a biochemical measure of the altered herbicide response. The experiment was conducted utilizing a two-factorial in a split plot design with four replications within blocks. Factor A was the rate of dicamba applied at either 0 or 5.6 g ae ha^{-1} at the third trifoliate growth stage of soybean. Factor B was the nine soybean lines that were purportedly determined have either low sensitivity (S17-1980, S16-12774, S17-5672, S14-1855, and S09-13608) or high sensitivity (S17-2615, PR17-510, S17-2625, and S17-3404) to dicamba. At 28 days after treatment, visual injury, percent of total nodes injured, and percent of total node reduction was lower in the S16-12774 and S14-1855 soybean lines in comparison to the S17-2615 and S17-3404 soybean lines. The concentration of ABA in the apical meristem for the less sensitive S16-12774 soybean line was reduced at 48 hour after treatment in. The concentration of ABA in the apical meristem for the less sensitive S16-12774 and the high sensitive S16-2625 was similar at 6 and 24 HAT, but ABA concentration was lower for the S16-12774 soybean line at 48 HAT. These results indicate that the S16-12774 and S14-1855 soybeans have decreased sensitivity to dicamba in comparison to the S17-2615 and S17-3404 soybean lines. In addition, the reduction in ABA concentration at the apical meristem for the S16-12774 soybean line is biochemical validation for the differential phenotypic response. Further greenhouse research will be conducted to determine the mechanism for decreased sensitivity as well as further characterize the role of ABA concentration over time in the apical meristem on the phytotoxic response in soybean from dicamba.

Variability in Response of Horseweed (*Conyza canadensis*) Populations to Dicamba and Glufosinate from Five Soybean Production States. Nick T. Harre*[1], Julie M. Young[2], Kevin W. Bradley[3], Karla L. Gage[4], Aaron Hager[5], Greg R. Kruger[6], Mark Loux[7], Jason K. Norsworthy[8], Larry Steckel[9], Bryan G. Young[10]; [1]Purdue University, West Lafayette, IN, [2]Affiliation Not Specified, Brookston, IN, [3]University of Missouri, Columbia, MO, [4]Southern Illinois University, Carbondale, IL, [5]University of Illinois, Urbana, IL, [6]University of Nebraska-Lincoln, North Platte, NE, [7]Ohio State University, Columbus, OH, [8]University of Arkansas, Fayetteville, AR, [9]University of Tennessee, Jackson, TN, [10]Purdue University, Brookston, IN (90)

Widespread resistance to glyphosate and ALS-inhibiting herbicides among horseweed [*Conyza canadensis* (L.) Cronq.] populations has placed greater reliance on dicamba and glufosinate for POST control. Although there have been no confirmed cases of horseweed resistance to dicamba or glufosinate to date, broad proactive screening efforts across time and space could potentially detect the onset of resistance before it reaches an unmanageable scale. Horseweed seeds (20 inflorescences) were collected from soybean fields prior to harvest across Illinois, Indiana, Missouri, Nebraska, and Ohio in 2018 (87 fields total) and 2019 (31 fields total). Composite populations were made for each field by combining seeds from individual plants. Screening was performed in the greenhouse the following summer by applying 1/4x and 1x field-use rates of dicamba (140 and 560 g ae ha^{-1}) or glufosinate (164 and 656 g ai ha^{-1}) to 5-cm rosettes ($n = 60$). At 21 d after treatment, control ratings of individual plants were used to calculate percent mortality for each population; mortality was defined as = 90% control. When treated with a 1/4x rate of dicamba, 21% and 13% of the 2018 and 2019 populations, respectively, had < 95% mortality. Control of individual plants within these populations ranged from 60% to 100% with an average of 94%. A population collected from Illinois in 2018 had 78% mortality from a 1x dicamba rate, yet further testing did not confirm resistance. Mortality was 100% for all 2019 populations treated with a 1x dicamba rate. When treated with a 1/4x rate of glufosinate, 56% and 90% of the 2018 and 2019 populations, respectively, had < 95% mortality. Control of individual plants within these populations ranged from 20% to 100% with an average of 97%. For both 2018 and 2019 populations, mortality was 100% when treated with a 1x glufosinate rate. The high degree of mortality from the 1x rates of dicamba and glufosinate indicates these herbicides remain viable options for horseweed control at present. However, the variability in response within and across populations to the 1/4x rates of dicamba and glufosinate reveals apparent sensitivity differences that may be exacerbated under continuous selection pressure.

Assessing Soil Variability in Commercial Fields and the Potential Impact on Weed Management. Rose V. Vagedes*[1], Bryan G. Young[2], William G. Johnson[1]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, Brookston, IN (91)

Progressively, site-specific crop management practices continue to be adopted by farmers to enhance the efficiency of crop production. Despite the advancements made to management practices such as a crop's seed and nitrogen inputs, most herbicide applications are still being applied at a uniform rate across an entire field. Commercially available and developmental technologies for site-specific weed management (SSWM) are currently limited to foliar-applied herbicides, which restricts SSWM usage to the period following weed emergence. Many soil-applied herbicides have application rate restrictions based on organic matter (OM), soil texture, cation exchange capacity (CEC), or pH. To optimize the effectiveness of these herbicides, multiple herbicide rates may need to be applied across a field. The potential for variable rate soil residual herbicide application may lead to further advancements for integrated weed management. However, the feasibility of this practice needs to be verified in commercial fields. Therefore, a survey will be conducted to (i) document the extent of variability in soil properties across commercial fields to justify site-specific soil residual herbicide application, and (ii) assess the utility of soil electrical conductivity (EC) measurements as a guided mapping tool to generate prescription maps for variable rate applications of soil residual herbicides. Site-specific soil EC data and soil samples will be spatially mapped using a semi-continuous, vehicle-mounted, electrical resistivity sensor, and traditional soil sampling for all commercial fields. These sensors measure electrical conductivity and have shown a strong correlation to organic matter and soil texture by previous research. Soil texture and OM results will be collected in a stratified random sampling pattern. Results from soil samples and soil EC will be interpolated with a form of geostatistics known as ordinary kriging to obtain a greater understanding of field spatial variability and cokriging to correlate spatial soil properties to EC data. Early data from two standard fields in Indiana display a 4- to 9-fold difference in soil EC variability. No sound conclusions can be drawn on spatial variability of soil texture, OM, and pH until soil samples are collected in the described methods. Future research will be conducted to fit soil residual herbicide application rates to the zone layers of prescription maps generated by spatial soil EC and soil samples.

Efficacy of Postemergent Formulated Dicamba, Glufosinate, Glyphosate, 2,4-D and Un-formulated Glufosinate on Common Lambsquarters. Ely D. Anderson*[1], Bruno C. Vieira[1], Jeffrey A. Golus[1], J Susan Sun[2], Greg R. Kruger[1]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]Croda Inc., New Castle, DE (92)

Multiple herbicide modes of action (MOA) in a given tank solution can help with preventing and controlling herbicide resistant weeds. Herbicide doses in multiple MOA tank-mixtures could affect their interaction and affect the control of the target weed species. Greenhouse research was conducted at the Pesticide Application Technology Laboratory (University of Nebraska-Lincoln, North Plate Nebraska) to better understand the efficacy of un-formulated glufosinate and formulated glyphosate, dicamba, 2,4-D, and glufosinate applied alone and in tank-mixture at two different doses on common lambsquarters (*Chenopodium album L.*). Common lambsquarters were grown to a height of 15 – 20 cm under greenhouse conditions and sprayed using a single nozzle spray chamber calibrated to deliver 140 Lha^{-1} with an AI95015EVS nozzle. Biomass was harvest 28 days after application and dried to a constant weight (65 C). Biomass was analyzed using ANOVA where means were separated at an $p = 0.10$. Weed control resulting from tank-mixtures of multiple herbicides were tested using the proposed equation from Colby. The experiment was a completely randomized design with six replications. Half and full label herbicide rates were used in this experiment to investigate the different interactions occurring amongst herbicides at different rates. Half rates of glufosinate, glyphosate, and glufosinate-glyphosate tank-mixtures resulted in <14% control. Half rates of growth regulators alone or with glufosinate controlled >57%. Full rate tank-mixtures of Liberty with Roundup PowerMax, Enlist 1 or Xtendimax had better control on common lambsquarters (<90%). Antagonism was observed when Liberty was tank-mixed with both glyphosate formulations at full rates. Overall, better control was observed when using full rates of all herbicides, however, mixing Liberty with both formulations of glyphosate at full and half rates resulted in antagonism amongst herbicides.

Effects of Drift-reducing Nozzles and Adjuvants on Dicamba Efficacy. Milos Zaric*, Kasey P. Schroeder, Jesaelen Gizotti de Moraes, Bruno Canella Vieira, Guilherme Sousa Alves, Jeffrey A. Golus, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (93)

The increase in cropping area with dicamba-tolerant crops in the US was followed with increased number of off-target movement (OTM) reported cases. The addition of drift-reducing adjuvants (DRAs) with certain tank-mixtures represents mandatory practice along with drift-reducing nozzle types. In general, the impact of these nozzles and DRAs on weed control is not well understood. The objectives of this study were to evaluate the impact of DRAs added to dicamba tank-mixtures on droplet size distribution (DSD) and control of velvetleaf (*Abutilon theophrasti* Medik.) and common lambsquarters (*Chenopodium album* L.). Examined factors included three levels of solution, nozzle type, and operating pressure. Solution was consisted of dicamba (diglycolamine salt) applied at 560 g ae ha^{-1} either alone or in tank-mixture with two DRAs at 0.5% v v^{-1}. The DRAs used were polyethylene glycol, choline chloride, guar gum (DRA 1) and 2-hydroxypropane-1,2,3 carboxylate, complex trihydric alcohols, oligomeric sugar alcohol condensates (DRA 2). Applications were made at 140 L ha^{-1} using TTI 11004, TDXL 11004-D, and ULD 12004 nozzles at 138, 207, and 276 kPa pressures. DSD was measured using a laser diffraction system in completely randomized design study with three replications. Efficacy studies were conducted in a randomized complete design and split-plot arrangement with four replications and three experimental runs. Pressure versus solution was considered as main plot and nozzle type as subplot. Prior to applications, twelve plants (10 to 15 cm tall) of each weed species per replication were arranged in a continuous line across width of the spray boom. Applications were made using a three-nozzle track spray chamber with nozzles spaced 50 cm apart and above target. Plants aboveground biomass were harvested 28 days after application and dried at 65 °C to a constant weight. Dry weight was converted into percentage of biomass reduction compared to non-treated control and further used to determine the coefficient of variation (CV) across the spray boom. Across all tested pressures, DSD values followed pattern with TTI>TDXL-D>ULD (largest to smallest) with decrease in percent of driftable fines observed when DRAs were used. The CV for velvetleaf control was about 5% indicating uniformity in biomass reduction across all treatments tested. For common lambsquarters, uniformity was treatment dependent with CV values ranging from 4 to 11%. The greatest difference was determined for treatments applied using low operational pressures and solution that did not contain DRAs. Even though spray pattern collapses are detected for TDXL-D and ULD nozzles at low operational pressures the addition of DRAs with dicamba in tank-mixture decreased the variation across spray boom. Solution, nozzle selection, and operating pressure need to be considered as critical component for both DSD and dicamba efficacy. Minimization of OTM is a priority, however, there is a critical need to determine which label approved mitigation practices are the most effective and which ones may be detrimental to optimize weed control.

Measuring Weed Control Efficacy in Small Research Plots Using Aerial Imagery. Lee A. Boles*[1], Ryan J. Edwards[1], Heather L. Matthees[2]; [1]WinField United, River Falls, WI, [2]WinField United, Arden Hills, MN (94)

Aerial imagery captured by unmanned aerial vehicles (UAVs) can be correlated to plant growth and environmental conditions. Utilizing near infrared (NIR) and red green blue (RGB) imagery a correlation to weed control efficacy can be established. Using indices such as canopy cover and normalized difference vegetation index (NDVI) values, ratings can be applied to the images per plot. By correlating plot indices to weed control ratings the study displayed similar significances in the treatment differences. The imagery was able to capture weed control ratings when the plot displayed herbicide activity.

Damage on Soybean Caused by Spray Drift from a Dicamba + Glyphosate Tank-mixture.
Antonio Augusto Correa Tavares*, Joao Victor de Oliveira, Rone Batista de Oliveira, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (95)

The use of glyphosate and synthetic auxin herbicides in tank mixtures is a feasible and effective alternative in weed management practices. However, drift reduction techniques are needed to avoid damages to nearby susceptible crops from these herbicide applications. The objective of this research was to determine the influence of boom height, work pressure, and nozzle design on spray drift and soybean injury in dicamba + glyphosate tank-mixture applications. The treatments were arranged in a completely randomized design in a 2x2x5 factorial scheme (nozzles x work pressure x boom height) with four replications. The spray solution corresponded to a tank mixture of dicamba (480 ai ha^{-1}) and glyphosate (1440 g ae ha^{-1}) prepared at a carrier volume of 130 L ha^{-1}. Applications were carried out using TTI11003 and AIXR11003 nozzles at 400 and 700 kPa in a research wind tunnel (Universidade Estadual do Norte do Paraná, Brazil). The wind tunnel is 20 m long with a 2.0 m square section and a 0.90 m diameter double-axial fan. The boom heights used were 0.35, 0.50, 0.75, 1.00 and 1.50 m from the ground. The airspeed was 3.0 m s^{-1} measured and monitored by a hot wire anemometer. Each replication was sprayed for 30 seconds, with the ventilation on for an additional 2 minutes. Potted soybean plants at V3 stage were positioned at five downwind distances (2, 5, 8, 10, 15 m) from the nozzle during applications. The weather conditions during trials were 23.4 ± 1.7°C and 51.3 ± 5.0% relative humidity. Following applications, soybean plants were maintained under greenhouse conditions and were evaluated for visual estimations of injury at 28 days after application (DAA). The plants that were at the furthest distance from the boom (15 m) had the lowest visual injury, ranging from 80% of damage for the treatment applied by AIXR 11003 at 700 kPa at boom height of 1.5 m to 10% for the treatment applied by TTI 11003 at 400 kPa and boom height of 0.35 m. For both nozzle types and working pressures used, increasing the boom height resulted in an increase in soybean injury. Applications made with the TTI 11003 at 400 kPa and boom height of 0.35 m resulted in lower damage to plants at distance of 5m from the nozzle (14%). The highest plant injury was recorded for applications with the AIXR 11003 nozzle at the highest work pressure and boom height (97%). The results indicate that the choice of nozzle design, working pressure, and boom height are important factors for mitigating drift and dicamba injury to sensitive crops.

Drift Potential of Glufosinate When Applied with a Single, Double or Triple Fan Nozzle.
Livia I. Pereira*, Leandro H S Guimaraes, Barbara Vukoja, Guilherme Sousa Alves, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (96)

Glufosinate is a nonselective herbicide that can cause damages on nearby susceptible crops due to spray drift depending on nozzle type and tank mix partners. The objective of this study was to evaluate the droplet spectra and drift potential from glufosinate applications using single, double, and triple fan nozzles in a wind tunnel. Glufosinate (655 g ai ha^{-1}) was applied alone or in tank mixture with three adjuvants: DRA (drift reducing adjuvant at 0.5% v v^{-1}), non-AMS WC (non-ammonium sulfate water conditioner at 0.75% v v^{-1}), and AMS WC (ammonium sulfate water conditioner at 5% v v^{-1}). Applications were made using single (AD 11002), double (AD/D 11002), and triple (AD/T 11002) fan nozzles at 206 kPa pressure. Droplet spectra parameters evaluated were Volumetric Median Diameter (VMD), percent fines (V_{141}) and relative spam (RS) measured using a laser diffraction system. The drift study was conducted in a completely randomized design in a 5 x 3 x 6 split-split-plot arrangement [solutions (main plot) versus nozzles (sub-plot) versus distances (sub-subplot)]. Applications were made at 4.5 m s^{-1} airspeed in a 1.2 x 1.2 x 15 m wind tunnel. Mylar cards (10 x 10 cm) were positioned at 1, 2, 3, 5, 8, and 12 m downwind from the nozzle. A fluorescent tracer was added to the solutions to be quantified by fluorometry. Droplet spectra and drift potential depended on the interaction between solution and nozzle type (? < 0.0001). Glufosinate plus DRA produced the coarsest VMD (364 to 420 µm) and smallest V_{141} (3.9 to 4.8%) across nozzle types. The addition of AMS WC adjuvant to the glufosinate solution decreased the VMD and increased the V_{141} in comparison with glufosinate alone using the AD/T nozzle. Across solutions and nozzle types, tracer deposition decreased exponentially as downwind distance from the nozzle increased. Within nozzle type, the lowest tracer deposition at 12 m was obtained using the DRA (2 to 13 g cm^{-2}). Glufosinate alone and in tank mixture with the other adjuvants produced similar drift potential at 12 m. The AD/T nozzle produced lower deposition at 12 m than AD/D nozzle across solutions. The AD and AD/T nozzles produced similar drift potential for glufosinate solutions with DRA adjuvant. The results indicate that interactions between nozzle type and adjuvants should be considered to mitigate drift potential from glufosinate applications.

Deposition of a Four Rotor UAS as Influenced by Flight Speed, Flight Height, and Nozzle.
Trenton W. Houston*, Brad K. Fritz, Clint W. Hoffmann, Antonio Augusto Correa Tavares, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (97)

UAS (unmanned aircraft system) applications have the potential to be efficient pesticide application platforms under conditions that are not accessible or fit for typical pesticide application equipment. Although this type of application is still under development in the U.S., UAS pesticide applications are common in Asia, as they have replaced backpack sprayers. Many parameters need to be investigated to identify the best combination of application variables such as flight height, flight speed, and nozzle selection. The objective of this research was to investigate different application variables for a UAS application platform. Research was conducted at the Pesticide Application Technology Laboratory in North Platte, Nebraska to better understand the swath width and deposition of a UAS. A four rotor UAS was used with a nozzle spacing of 76 cm and a fight height of 1m and 3m using XR800015, AIXR110015, and AITX110015 nozzles. Tank solution including tracer (5 g L^{-1} of bright blue, Spectra Colors Corporation) was applied on 2.54x7.6 cm photopaper cards spaced at 0.5m spacing across a 15-m sampling line. Cards spray coverage was analyzed using AccuStain (v.35.5). The experiment was conducted in a complete randomized design with a factorial treatment arrangement including flight height, speed, and nozzle type as factors. Spray coverage data were submitted to ANOVA using PROC GLIMMIX in SAS (SAS v9.4, SAS Institute Inc., Cary, NC, UAS). Comparisons among treatments were performed using Fishers protected LSD procedure (0.1 alpha level). Flight height ($p<0.2083$) and a nozzle*speed interaction ($p<0.0705$) influenced spray coverage. The XR nozzle at 2.7 m s^{-1} provided the best spray coverage (3.4%) while the AIXR and AITX nozzles were not different at 2.7 m s^{-1}. At the 5.4 m s^{-1} flight speed spray coverage was similar for tested nozzles (0.7-1.1%). More spray coverage was observed at the 1-m flight height (1.9%) compared to the 3-m flight height (1.5%). A better understanding on nozzle selection and application parameters will be important to optimize pesticide applications while mitigating spray drift potential for UAS pesticide applications.

Evaluation of Dicamba Vapor Reducing Agents Across Different Environments. Sarah V. Striegel*[1], Ryan D. Langemeier[2], Bruno C. Vieira[3], Steve Li[2], Greg R. Kruger[3], Rodrigo Werle[1]; [1]University of Wisconsin-Madison, Madison, WI, [2]Auburn University, Auburn, AL, [3]University of Nebraska-Lincoln, North Platte, NE (98)

Several application and environmental factors can influence potential for dicamba off-target movement. For instance, inclusion of glyphosate in solution with dicamba has been reported to reduce spray solution pH, often below the label-recommended level of 5.0, increasing detectable dicamba air concentrations. The recent 2020 approval of DR-soybean dicamba products now requires addition of a pH buffering agent (e.g., volatility reducing agent [VRA]); however, more research is needed to understand how these products affect solution pH and secondary dicamba movement. In 2020, a low tunnel volatility experiment was conducted in Alabama and Wisconsin to evaluate the impact different dicamba VRA have on solution pH and soybean injury occurring as a result of dicamba volatility. Our hypothesis was that all dicamba VRA used would increase spray solution pH above 5.0, decrease detectable dicamba air concentration following application, and reduce subsequent soybean injury. Treatments included 560 g ae ha^{-1} *N*, *N*-Bis-(3-aminopropyl)methylamine (BAPMA) salt of dicamba plus 1260 g ae ha^{-1} potassium salt of glyphosate (gly) (1) alone, and with a VRA addition: (2) agripotash, (3) potassium acetate, (4) potassium hydroxide, (5) tripotassium phosphate, (6) potassium carbonate, (7) sodium borate, and one nontreated control. Treatments were sprayed twice in succession to soil flats at an offsite location, immediately transported to the field, and four soil flats were carefully placed between two soybean rows at V3 to V5 growth stage under constructed low tunnels. Low-volume air samplers were positioned in the center of the plot, equipped with polyurethane foam (PUF) tubes, and calibrated to 3 L min^{-1}. Soil flats and tunnels were removed and PUFs were collected 48 h after application. PUFs were stored at -20 C and shipped to Mississippi State Chemical Laboratory for dicamba concentration analysis via liquid chromatography. Meteorological data were collected at all locations for the duration of the experiments. Visual estimations of soybean injury were collected 28 d after treatment. Soybean injury over distance was used to estimate the area under injury over distance stairs (AUIDS) to represent both severity and extent of symptomology throughout treatment plots. Treatments with a VRA included had higher solution pH (5.34-7.49) compared with the BAPMA + gly treatment (4.67-4.94). The dicamba concentration and AUIDS values were higher in Alabama compared with Wisconsin, which may be attributable to difference in meteorological conditions following application. Treatments with a VRA had lower AUIDS (<50) compared with BAPMA + gly alone (AL: 150.7; WI: 67.1) at both locations. Similarly, dicamba concentration was lower for most treatments with a VRA (AL: 0.44-2.63; WI: 0.31-1) included when compared with the BAPMA + gly treatment (AL: 12.8; WI: 2.4). Moreover, there were few differences in AUIDS and dicamba concentration amongst the VRA treatments. Our results indicate that there was a clear benefit to adding a VRA in order to reduce dicamba volatility and subsequent soybean injury. More research is needed to understand the role of such tank additives on weed control, crop safety, and volatility under large scale field conditions.

Influence of Surfactant-humectant Adjuvants on Efficacy of Glufosinate Herbicides on Horseweed and Palmer Amaranth Control. Estefania Gomiero Polli*[1], Guilherme Sousa Alves[1], Frank Sexton[2], Greg R. Kruger[1]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]Exacto, Inc, Sharon, WI (99)

Glufosinate efficacy is inconsistent among weed species and under environmental conditions that favor rapid droplet-drying. Surfactant-humectant adjuvants could optimize glufosinate efficacy by increasing wetting, penetration into the leaf surface, and droplet-drying time. Therefore, the objective of this study was to investigate the influence of surfactant-humectant adjuvants on the efficacy of two glufosinate herbicides on horseweed (*Erigeron canadensis* L.) and Palmer amaranth (*Amaranthus palmeri* S. Watson) control. Horseweed studies were conducted in North Platte, NE in 2019 and in Paxton-NE in 2020, and Palmer amaranth study was conducted in North Platte, NE in 2020. Trials were randomized in a complete block experimental design with a 2 x 7 factorial arrangement and 4 replications with 2 runs for horseweed and a single run for Palmer amaranth. Spray solutions were prepared using each glufosinate herbicide at 656 g ai ha^{-1} alone or tank-mixed with six experimental surfactant-humectant adjuvants. Ammonium-sulfate was added to all treatment solutions to neutralize hard water antagonistic effects. Horseweed (50 cm tall) and Palmer amaranth (40 cm tall) plants were sprayed using a CO2 pressurized backpack sprayer, respectively, with TTI110015 nozzles calibrated to deliver 140 L ha^{-1} with a pressure of 276 kPa. A total of 10 arbitrary plants were marked per plot before application, and at 28 days after application (DAA), they were harvested and oven-dried (65 C) until constant weight. The addition of surfactant-humectant adjuvants to glufosinate solutions did not increase horseweed and Palmer amaranth control for both herbicides. Overall, average biomass reduction after glufosinate applications were 68% and 72% for horseweed and Palmer amaranth, respectively. Herbicide-adjuvant-plant-environment interactions are complex and, thus, surfactant-humectant adjuvants may not increase glufosinate efficacy.

Glufosinate Control and Physical-chemical Properties with Different Adjuvants on *Chenopodium album* and *Bassia scoparia*. Joao Victor de Oliveira*[1], Antonio Augusto Correa Tavares[1], Estefania Gomiero Polli[1], Leandro H S Guimaraes[1], Jesaelen Gizotti de Moraes[1], Rone Batista de Oliveira[2], Greg R. Kruger[1]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Northern Paraná, Bandeirantes, Brazil (100)

To obtain satisfactory weed control using contact herbicides, such as glufosinate, it is necessary for adequate coverage and deposition. Physical properties of herbicide on leaf surfaces can influence herbicide performance, as well as leaf surface morphology. Adjuvants are capable of modifying these physical properties of the solution. The objective of this research was to determine how glufosinate solutions with different physical properties can affect the control of common lambsquarters (*Chenopodium album*) and kochia (*Bassia scoparia*). Plants were grown under greenhouse conditions and were conducted in a completely randomized design with and four plants, one per rep (14 to 19 cm tall) the treatments were sprayed with a three-nozzle spray chamber calibrated to deliver 140 L ha^{-1} using TT11002 nozzles spaced by 51 cm at 276 kPa and 1.77m s^{-1} travel speed. Applications were made using glufosinate-ammonium (328 g ai ha^{-1}) applied in a mixture with nine adjuvants: nonionic surfactant (0.37% v v^{-1}), organo-silicone surfactant (0.18% v v^{-1}), high surfactant oil concentrate (0.5% v v^{-1}), modified vegetable oil (0.5% v v^{-1}), drift reduction agent (0.5% v v^{-1}), crop oil concentrate (1.67% v v^{-1}), humectant (0.5% v v^{-1}), and ammonium sulfate (5% v v^{-1}). After applications, plants were clipped at the soil surface at 28 days after treatment and placed in a dryer for seven days at 65 C. Dry biomass was recorded and converted into percent biomass reduction. Density and viscosity measurements were made at 20 C, for density was used the fade-out method (DMATM 4500 M density meter) and for viscosity Hoeppler's falling ball principle (Lovis 2000 M/ME microviscometer). Dry weight, density, and viscosity were analyzed separately and subjected to ANOVA with mean separations made at a = 0.05 level using Fisher's protected LSD test and Tukey adjustment. The highest values of density were in the solutions of glufosinate plus water conditioner (1.0142 g cm^{-3}) and silicone (1.0008 g cm^{-3}), and for viscosity glufosinate plus drift reduction adjuvant (1.3842 mPa s) and crop oil concentrate (1.1390 mPa s). The biggest difference for density was 1.57% between glufosinate plus water conditioner (1.0142 g cm^{-3}) and crop oil concentrate (0.9983 g cm^{-3}), and for viscosity was 26.22% between glufosinate plus drift reduction adjuvant (1.3842 mPa s) and glufosinate alone (1.0212 mPa s). Significant interaction between spray solution and weed species was observed on control. For common lambsquarters, the highest control was obtained with solutions containing glufosinate plus water conditioner (94.7%), drift reduction adjuvant (94.0%) and high surfactant oil concentrate (93.9%), and the lowest control was obtained with glufosinate plus silicone (33.6%). For kochia, the highest control was obtained with solutions containing glufosinate plus water conditioner (94.5%), humectant (94.3%), drift reduction adjuvant (93.6%), nonionic surfactant (93.4%) and high surfactant oil concentrate (91.2%), and the lowest control was obtained with glufosinate plus silicone (13.8%).The treatments with the greatest density and viscosity values obtained resulted in control greater than 90% in both species. Different adjuvants tank-mixed with glufosinate changed the physical properties of the spray solution but an association with weed control was not observed.

Influence of Droplet Size in Control of Velvetleaf and Lambsquarter Treated with Fomesafen. Vitor M. Muller Anunciato*[1], Antonio Augusto Correa Tavares[1], Joao Victor de Oliveira[1], Jesaelen Gizotti de Moraes[1], Caio A. Carbonari[2], Greg R. Kruger[1]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]UNESP, Botucatu, Brazil (101)

Velvetleaf (*Abutilon theophrasti*) and common lambsquarters (*Chenopodium album*) are common weeds in soybean and corn fields, frequently controlled using post-emergent and systemic herbicides. Due to the increase of resistant weeds to these herbicides, the use of contact herbicides has been an alternative in weed management practices. The objective of this study was to evaluate the effect of droplet size on velvetleaf and c. lambsquarters control for fomesafen applications. Two studies were conducted in a completely randomized design with a 5 x 4 factorial arrangement with four replications. The treatments were five rates of fomesafen (53, 106, 213, 426, and 852 g ai ha^{-1}) and four droplet size spectrums. Treatments were applied using a sprayer chamber calibrated to deliver a spray volume of 190 L ha^{-1}. Applications were performed with ER110015 (413 kPa at 1.19 m s^{-1}), SR11005 (206 kPa at 2.85 m s^{-1}), DR11005 (413 Kpa at 4.04 m s^{-1}), and UR11004 (310 kPa, 2.98 m s^{-1}) nozzles. These nozzles represent fine, medium, very coarse, and ultra coarse droplet size, respectively. At 28 days after treatment, plants were harvested, oven-dried at 65°C to constant weight and above-ground biomass was recorded. Generalized additive modeling (GAM) analysis was conducted in R 3.5.0. statistical software using the mgcv package to model control of velvetleaf and lambsquarters. Models consisted of one smoothed variable (rate) and smoothing parameters were estimated separately for each droplet size. Lambsquarter had an unsatisfactory control presenting a linear tendency of control increment but in the lowest doses the control is around 50% and in the highest doses there is a small increase reaching 65%, the exception is the treatments with the drops classified as average according to ASABE, in this treatment the control reaches 72%. Velvetleaf also showed low control not changing even with the increase in dose, the excesses are the ultra coarse drops that have the linear tendency coming out of 40% at the lowest dose and reaching 60% and the average drops reaching 88% in the dose of (610 g ia ha $^{-1}$), reducing the control reaching 68% control in the highest dose (1008 g ia ha^{-1}). For the two species (*A. theophrasti*) and (*C. album)* the control was not satisfactory and the media shadings were the ones that promoted the best control result.

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Analyzing Spray Coverage and Herbicide Efficacy with Hypro ULD Nozzles for Liberty and Enlist Tank Mixtures. Josh Skelton*, Anderson Weber, Aszhia Albrecht, Amanda Flipp; WinField United, River Falls, WI (102)

Factorial arrangement of 2 trials and 5 replications totaling to 10 experimental units per plant species. One card was placed at the top of each canopy with a total of 10 spray cards per treatment across the entire study. Liberty and Enlist One tank mixes were compared with the addition of adjuvants. Addition of Enlist One plus the adjuvant performed better in terms of spray coverage, reduced drift, and efficacy. Also, 50 PSI compared to the 30 PSI with Enlist One + the adjuvant reduced the number of droplets.

Efficiency of Tank Cleaning Different Dicamba Formulations. Vinicius Velho*, Guilherme Sousa Alves, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (103)

Several dicamba formulations are available in the market. Regardless of the product, three rinses are required by label for cleanout procedures. By the reason of dicamba activity in low doses on susceptible crops such as soybean, tank cleaners have an important role in breaking down residues facilitating their removal by rinses. The objective of this study was to evaluate the effect of five commercial products and the use of tank cleaner on the rinsate of non-dicamba tolerant soybean. The study was conducted in the summer of 2020 in Stapleton, NE. Five commercial dicamba products were used with the addition of one tank cleaner in the second rinse. Three rinsates were collected, the fourth collection was obtained by filling the tank to simulate a future application. These solutions were sprayed on soybeans at R1 stage using a backpack sprayer calibrated to deliver 140 L ha^{-1} with AIXR 11002 nozzles. Treatment structure was 6x4 multiple factor factorial, the factors being commercial dicamba product and rinse. Visual injury, plant high at 28 days and at harvest and yield was analyzed using Fisher's Protected LSD test at a = 0.05 using SAS version 9.4. Results obtained showed main effects of rinse (p-value<0.001) and mixture (p-value=0.0161) and an interaction between rinse and mixture (p-value=0.0096) .Visual estimation of injury in the first three rinses and a plant height reduction at harvest being significant for commercial products used. No difference between formulations were observed in the first rinse and Status® herbicide estimated the least visual injury in the second and third rinse. No visual estimation of injury was observed in the follow-up application. Even though visual estimation of injury was observed in the third rinse, there was no difference in plant height between XtendiMax®, Diflexx® and the untreated control. Proper tank cleaning following dicamba application is essential to ensure safe pesticide applications to dicamba-sensitive crops.

Single vs Twin Fan Nozzle Coverage on Broadleaf Weeds. Jessica B. Oliveira*, Bruno C. Vieira, Kasey P. Schroeder, Jeffrey A. Golus, Greg R. Kruger; University of Nebraska-Lincoln, North Platte, NE (104)

The selection of nozzle type is one of the crucial parameters of herbicide applications. Droplet size directly affects the efficacy of a given herbicide through changes in coverage and deposition. The use of twin jet fan nozzles with non-vertical sprays was reported to improve spray coverage on certain targets and consequently increase pesticide efficacy. Therefore, the objective of this study was to evaluate the spray coverage and weed control of dicamba applications using single and double fan nozzles. The study was conducted at the Pesticide Application Technology Laboratory (University of Nebraska-Lincoln) in a completely randomized design with ten plants and eight Kromekote cards replications in two independent experimental runs. Three weed species were used: kochia (*Bassia scoparia*), Palmer amaranth (*Amaranthus palmeri*) and common lambsquarters (*Chenopodium album*). Plants were grown under greenhouse conditions to a height of 22-33 cm. Dicamba (560 g ae ha^{-1}) applications were performed using a three-nozzle research track spray chamber calibrated to deliver 140.3 L ha^{-1} using 5 different nozzles (TTI11004, TDXLD11004, ULD12004, TTI6011004, and TADFD04) at 276 kPa. Spray solution also included Intact (0.5% v/v) and 1 g L^{-1} of blue dye (bright greenish blue/food blue 002, Spectra Colors Corporation) for spray coverage scan analysis. Kromekote cards (24 cm^2, Mill CTI Paper USA) were positioned horizontally and vertically in stands to collect spray deposits during applications. Cards were scanned and evaluated for spray coverage using Accustain software (University of Illinois Urbana-Champaign, IL, USA). Plant above ground biomass was harvested at 28 days after treatment and oven dried at 65?°C to constant weight. Biomass data were converted into percentage of biomass reduction as compared to the untreated control. Biomass reduction and spray coverage data were analyzed with a generalized mixed model in SAS software (SAS v9.4, SAS Institute Inc., Cary, NC, USA) and comparisons among treatments were performed using Fisher's least significant difference procedure at significance level a?=?0.05. The interaction of nozzle design and Kromekote cards position influenced spray coverage (p = 0.0037). Spray coverage on horizontal cards ranged from 25.1 to 35.5% for the nozzles tested herein, whereas spray coverage on vertical cards ranged from 5.3 to 8.5%. The twin fan nozzle TADFD04 had superior spray coverage on horizontal cards (35.5%) compared to the single fan nozzle TTI11004 (29.3%). However, the TADFD04 double fan nozzle had similar spray coverage on horizontal cards compared to the single fan nozzles TDXLD1104 (34.5%) and ULD12004 (33.3%). The twin fan nozzle TTI6011004 had the lowest spray coverage on horizontal cards (25.1%) for the nozzles tested herein. Spray coverage on vertical cards was similar among all nozzles tested in this study. Despite differences in spray coverage on horizontal cards, nozzle design did not influence dicamba control on kochia, Palmer amaranth and common lambsquarters (p = 0.48). Kochia had increased dicamba control (67%) compared to Palmer amaranth (61%) and common lambsquarters (61%) when nozzles were pooled. The advent of double fan nozzles did not improve weed control for dicamba applications in this study.

Weed Seed Dispersal Management Outreach– Wisconsin Combine Cleaning Clinic. Daniel H. Smith*, Nicholas J. Arneson, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (105)

Weed seed management to prevent the spread of troublesome and herbicide-resistant weeds has been the focus of multiple outreach efforts in the US North Central region. Since 2017, an outreach effort from the University of Wisconsin-Madison has focused on combine cleaning. Extension specialists and outreach staff presented 6 combine cleaning clinics teaching >150 producers, Extension staff, and conservation professionals how to properly and safely clean a combine to reduce weed seed movement and the importance of such practice. These clinics are a three hour hands-on event that cover weed biology, weed seed production and retention, identification of troublesome weeds, and demonstrations of how to safely and effectively clean a combine to minimize further dispersal of weed seeds during crop harvest. Cleaning a combine for weed seeds takes approximately 30 minutes and should focus on the main areas where weed seeds can hide, including the grain platform/corn head, feeder house, rock trap, and rotor. In 2019-2020 we conducted a case study to gather empirical evidence that combines can harbor and spread weed seeds (please see the abstract “Weed Seed Dispersal Management Outreach– Wisconsin Combine Case Study” by Arneson et al.). Moreover, “Preventing Weed Seed Movement via Combines” was a featured presentation in two large Extension programs in Wisconsin (attended by more than 600 agronomists). While farmers and commercial harvest crews are typically running against time during crop harvest, taking time to clean the harvesting equipment is important to minimize the spread of weed seeds from field to field. In this era of widespread resistance and shortage of effective chemical weed control options, proper seedbank management represents a foundation for sustainable long-term weed control; herein and in our training programs we make the case that a 30-minute time investment to clean a combine can save them a substantial amount of money down the road. Lastly the University of Wisconsin, via a protocol from the North Central Region Agriculture and Natural Resources Cropping Academy, developed a video on how to clean a combine. This YouTube video (https://go.wisc.edu/tcj5cq) provides details using a top-to-bottom, front-to-back procedure with multiple helpful solutions on cleaning a combine for weed seed management.

Weed Seed Dispersal Management Outreach – Wisconsin Combine Case Study. Nicholas J. Arneson*, Daniel H. Smith, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (106)

Managing the spread of herbicide resistance starts with effective weed seedbank management. Several of the troublesome weeds in Wisconsin corn (*Zea mays* L.) and soybean (*Glycine max* L. merr) fields [e.g., pigweeds (*Amaranthus* spp.), ragweeds (*Ambrosia* spp.), common lambsquarters (*Chenopodium album* L.)] retain most of their seeds through the time of harvest. Due to their late season seed retention, seeds from these weed species can be effectively dispersed via combines. Even with this knowledge in hand, combine cleaning does not appear to be a common practice in Wisconsin. A case study was conducted in 2019-2020 by the UW-Madison Cropping Systems Weed Science Lab in collaboration with UW Extension to demonstrate the effectiveness of commercial combines in harboring and spreading weed seeds. This study targeted four critical components of a commercial combine: the grain platform or head, feeder house, rock trap, and rotor. We received 31 total samples from nine separate combines. Samples were mixed with 50:50 ratio of PROMIX HP potting mix and a silt loam soil, spread across 0.15 m^2 greenhouse flats, and watered daily. Emerged plants (weeds and crops) were counted two weeks following study establishment. Emerged weeds were observed in 97% of samples consisting of nine different weed species/families. The number of emerged weeds collected from the critical components of the combines were not statistically different in number of species observed and number of emerged weeds ($P>0.05$). The samples from the combine head/platform produced the most weed specimens containing nearly 49% of total weeds observed. Annual grasses, pigweeds and common lambsquarters were the three most commonly observed weeds. The results from this study provide empirical evidence that weed seeds are retained to and can move from field to field via combines emphasizing the importance of taking the time to i) ensure weeds do not set seed and ii) clean these critical combine components free of debris after harvesting weedy fields.

North Central Weed Science Society Meeting Papers and Posters: an Overview of the Past 20 Years Using Text Analysis. Maxwel Coura Oliveira*[1], Sarah M. Matos Marinho[2], Rodrigo Werle[1]; [1]University of Wisconsin-Madison, Madison, WI, [2]University of Sao Paulo, Sao Paulo, Brazil (107)

The first North Central Weed Science Society (NCWSS) annual meeting was held in 1945 in Omaha, NE. The NCWSS has since become an annual tradition for Weed Science students and professionals in the public and private sectors from across the US North Central region. The annual meeting proceedings include the abstracts of papers and posters presented each year, which likely reflect the current weed management challenges and research priorities faced by stakeholders and researchers in the NC region at the time of each meeting. With advances in technology, the proceedings of the NCWSS annual meetings from 2001 onwards have become publicly available as a pdf document. Our objective was to conduct a text analysis using the NCWSS annual proceedings to evaluate the major weed and herbicides being investigated by our society during 2001-2019. The text analysis was completed in R statistical software using packages corpora, tidyverse, tidytext, topicmodels, pdftools, and tm. The proceedings from each annual NCWSS meeting (pdf file) was imported into R, title and abstracts (from posters and papers) were processed with R functions to remove authors names, numbers, punctuation, and stop words. Weeds with multiple common names such as horseweed and marestail were combined into one (e.g., horseweed). The frequency of each word from each processed and cleaned NCWSS yearly proceedings were ranked from 1 to 100, being 1 and 100, the first and hundredth most frequent word in each annual proceedings, respectively. We focused on two groups of words, herbicides and weeds, that made the top 100 words in the NCWSS of 2001 and 2019. Results showed that from 2001 to 2015 glyphosate was among the top 4th words and thus the top herbicide in the NCWSS annual meetings. From 2016 onwards, dicamba surpassed glyphosate as the top herbicide word in the NCWSS meetings. In 2019, dicamba was ranked the 5th word, followed by glyphosate, 2,4-D, and glufosinate. In 2001, herbicides such as metolachlor, clopyralid, foramsulfuron, and imazethapyr were in the top 100 words but these herbicides are no longer in the top 100 as of 2019. Moreover, results demonstrated a weed shift from 2001 to 2019. For example, among the top 100 words of the NCWSS proceedings in 2001 were seven words related to weed species: waterhemp, foxtail, velvetleaf, grass, nightshade, ragweed, and sunflower. Among the weeds in 2001, only waterhemp is still present in the NCWSS in 2019. Waterhemp had a decrease from 2001 to 2006 but a steep increase since 2007. Similar trend was observed with palmer and amaranth words, which represents Palmer amaranth. Other two complete the weed words in the top 100 in 2019, including horseweed and kochia. Other herbicides and weeds likely made the top 100 words between 2002 and 2018. Results presented here reflect the weed management challenges and research priorities across the NC region: management of species that have evolved resistance to several herbicide sites of action (e.g., waterhemp, Palmer amaranth, horseweed) and herbicides associated with the novel soybean herbicide tolerance traits (dicamba, glufosinate, 2,4-D).

Creating an In-person, Self-guided Research Plot Tour. Ryan P. Miller*[1], Lisa M. Behnken[1], Phyllis M. Bongard[2]; [1]University of Minnesota, Rochester, MN, [2]University of Minnesota, Farmington, MN (108)

To comply with public health guidelines, an in-person "self-guided" research plot tour was developed to replace our traditional in-person weed management tour event. Typically, approximately 100 farmers and ag professionals have attended our annual corn and soybean weed management tours. Research trials focus on new herbicides, herbicide systems, and novel ways to manage weeds including cultivation and the use of cover crops in corn and soybeans. Participants would be divided into three groups that would make tour stops to learn about university and industry sponsored weed management research projects. In the days and weeks following our formal tour days, interested groups and individuals would continue to visit the research site to learn about the various weed management projects. During 2020, to meet the educational needs of participants and comply with public health guidelines, we developed the "self-guided" tour. It was modeled after an experience you might have on an interpretive nature trail or at an art museum. To accomplish this, a series of eight audio recordings were developed and hosted as MP3 files on Amazon Web Services (AWS). QR codes were printed on plot signs and these were posted at the tour stops. Participants could scan the QR code with their smartphones and listen to the audio file that provided an interpretation or explanation of the tour or tour stop. In addition to the tour stop narration, a paper tour report was collated and placed in a mailbox at the research site so participants could take a copy with them on the self-guided tour. We also provided a map of the site and hand sanitizer in the mailbox for participants to use. We numbered the paper tour reports to keep track of the inventory and were able to determine 27 copies had been taken home by participants. We also believe that some individuals took paper reports for the tour and then replaced them in the mailbox when they were finished with the self-guided tour. AWS allows for tracking of audio file use and we had 337 listens to the eight files, including 66 listens to the tour introduction file which served as the first stop on the self-guided tour. Feedback was favorable, as this was one of the only non-virtual in-person events of the summer. Based on our 2020 experience, we will consider using the self-guided method in the future to improve access for people who may not be able to attend the traditional tour and to expand and enhance our educational outreach efforts.

Evaluation of Poison Hemlock Control Options. Joe Omielan*; University of Kentucky, Lexington, KY (109)

Poison hemlock (*Conium maculatum*) is a highly toxic biennial, listed as a noxious weed in Kentucky, that is a common problem on right-of-ways. The seeds germinate in the fall, but the plant usually does not bolt and produce flowers until the second spring, which is when they are most noticeable. This trial evaluates a number of herbicide control options including new formulations of 2,4-D with lower volatility (DMA4 vs Freelexx) plus the new formulation of triclopyr (Garlon 3A vs Vastlan). The trial was established May 7, 2018 on an area mowed once a year along I75 near Richmond, KY with a thick stand of poison hemlock. The trial had 9 treatments with 3 replications arranged in a RCBD design with 2.1 m by 7.6 m plots. Application was at 187 L ha^{-1}. The poison hemlock plants had bolted (80 to 120 cm tall) but not yet flowered. There were also Canada thistle (*Cirsium arvense*) plants (average of 60 cm tall) and common teasel (*Dipsacus fullonum*) plants (average of 30 cm tall) in most of the plots at application. Plots were assessed visually 9 (5/16/2018), 52 (6/28/2018), and 374 (5/16/2019) days after treatment (DAT). It was not possible to assess the plots later in the 2018 season as giant foxtail (*Setaria faberi*) was covering the treated plot area. Vetch (*Vicia sp*) was covering the control plot area. Data were analyzed using ARM software and treatment means were compared using Fisher's LSD at p = 0.05. All the herbicide treatments contained the adjuvant, Activator 90 at 0.25% v/v. Trt 1: DMA3 @ 9.4 L ha^{-1} Trt 2: Freelexx @ 9.4 L ha^{-1} Trt 3: Milestone (aminopyralid) @ 0.37 L ha^{-1} Trt 4: Method (aminocyclopyrachlor) @ 1.1 L ha^{-1} Trt 5: Solution Water Soluble (2,4-D) @ 2.56 kg ha^{-1} Trt 6: Garlon 3A @ 3.5 L ha^{-1} Trt 7: Vastlan @ 2.6 L ha^{-1} Trt 8: Opensight (aminopyralid + metsulfuron) @ 175 g ha^{-1} Trt 9: Nontreated Check All the herbicide treatments had dramatic effects on the tall poison hemlock plants 9 DAT. There were no differences in control between the DMA 4 and Freelexx formulations 9 or 52 DAT. However, the older Garlon 3A was slower (33% control) than Vastlan (50% control) 9 DAT but had the same % control at 52 DAT (97 to 98% control). Most of the hemlock plants were brown and dry 52 DAT but there was still some green tissue and % control was lower for the Milestone and Opensight than the other treatments. Method had the best early control (55%) on common teasel but it was not possible to get teasel rating on the second date. The best early control ratings on Canada thistle (50 to 63% control) were for DMA 4, Milestone, Solution Water Soluble, and Opensight 9 DAT. An early spring assessment was done in 2019 to evaluate if there is extended control with soil residual herbicides, like Milestone, Method, and Opensight but there was too much variability among the plots. However, there were no teasel plants in any of the Method plots 374 DAT.

Garlic Mustard Monitoring Efforts Inform a Coupled Weed-herbivore Population Model for Simulating the Release of Potential Biocontrol Agents. Mary Marek-Spartz*[1], Roger Becker[1], George Heimpel[1], Lori Knosalla[2], Rebecca Montgomery[1], Laura Van Riper[2]; [1]University of Minnesota, St. Paul, MN, [2]Minnesota Department of Natural Resources, St. Paul, MN (110)

Garlic Mustard (*Alliaria petiolata*) is an invasive biennial forb of forest understories threatening native spring ephemerals and tree seedlings. Because it is a weed in sensitive forest ecosystems, herbicide treatments are not always feasible. The imported biological control agent, *Ceutorhynchus scrobicollis* is currently prioritized as a management option for *A. petiolata* in North America, and the host-range testing is almost complete for another potential agent, *Ceutorhynchus constrictus*. Pre-release monitoring of *A. petiolata* populations can establish baseline information about the site-specific population dynamics of the weed and inform agent release efficacy. In 2005 and 2006, twelve Minnesota sites were established for monitoring *A. petiolata* ahead of approval for a release of *C. scrobicollis.* During delays in the petition process for *C. scrobicollis*, the dynamics of garlic mustard populations changed at these sites. In June of 2018 and 2019, belt transects were used to more extensively monitor *A. petiolata* populations at four of the original locations. Population densities of first-year seedlings and second-year *A. petiolata* were surveyed at each site. Plant-stage transition and density data collected from these transects was used to parameterize a coupled weed-herbivore model to run simulations of the population dynamics between garlic mustard and the rosette crown-miner, *C. scrobicollis*.

An Update: Biological Control of Garlic Mustard with Crown-Boring and Seed-Feeding Weevils. Jeanie Katovich*[1], Roger Becker[1], Ghislaine Cortat[2], Hariet Hinz[2], Laura VanRiper[3], Mary Marek-Spartz[1]; [1]University of Minnesota, St. Paul, MN, [2]CABI, Delemont, Switzerland, [3]Minnesota Department of Natural Resources, St. Paul, MN (111)

Garlic mustard (*Alliaria petiolata)* is an invasive biennial plant native to Europe and, in North American, poses a threat to native herbaceous and woody plants in the forest understory. Biological control would provide long-term management of this invasive plant. Two of the most promising biocontrol insects are the European weevils, *Ceutorhynchus scrobicollis,* a crown-miner and *Ceutorhynchus constrictus,* a seed-feeder. The crown-mining weevil is predicted to have the most significant impact on garlic mustard plants. However, release of a single control agent is unlikely to control garlic mustard across its full range. It has been predicted that a combination of agents that simultaneously reduce rosette survival and seed production will be required to suppress the most vigorous garlic mustard populations. This is the rationale for developing the seed feeder, *C. constrictus* as a biological control insect. This seed-feeder can destroy up to 60% of developing seeds in a population of garlic mustard, reducing the severity of an infestation through a reduction in the seedbank. Host-range testing has been completed for *C. scrobicollis* and the agent has been recommended for release by the Technical Advisory Group for the Biological Control of Weeds and is currently under review by APHIS-PPQ. Host specificity testing of the seed-feeder is well advanced and so far, has shown a very narrow host range for this species. The biology of the two potential biocontrol agents, and their impact on garlic mustard plants are described in this poster.

Effect of Row Spacing and Overlapping Residual Herbicides in 2,4-D and Isoxaflutole-resistant Soybeans. Chad J. Lammers*, Sarah Lancaster, Tyler P. Meyeres; Kansas State University, Manhattan, KS (112)

Managing herbicide-resistant weeds is very challenging, with weeds developing more resistance to herbicides each year. An integrated approach is needed to properly manage herbicide-resistant weeds and have less reliance on herbicides. Narrow row-spacing limits sunlight to weeds, potentially improving weed control. Best practices also include the use of overlapping residual herbicides applied postemergence to the crop. In addition, herbicide traits influence weed management options. More research is needed to compare the effectiveness of integrated weed management strategies in differing herbicide-resistant soybean varieties. In this study, two herbicide-resistant soybean systems: 2,4-D-, glyphosate-, and glufosinate-resistant and isoxaflutole-, glyphosate-, and glufosinate-resistant were grown to evaluate weed control with 36- and 78-cm row spacing and level of management. Low management had a PRE treatment alone, while the medium management level added a POST treatment and the high management level added soil residual to the POST. Plots were evaluated every 2 weeks after the application of the PRE herbicide for 16 weeks. The weed control of Venice mallow (*Hibiscus trionum*), common waterhemp (*Amaranthus tuberculatus),* crabgrass (*Digitaria sanguinalis),* and prickly sida (*Sida spinosa*) and percent of crop canopy cover were taken visually. Weed biomass was collected using a 0.5 m^2 from each plot in July and September. Samples were dried at 50 °C. The center 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, a = 0.05) using the packages lmer, anova, and emmean in R. The medium and high management strategies resulted in ≥ 98% weed control, compared to 75-82% for the low management strategy. No significant differences in weed biomass were observed in July or September. Enlist E3 soybeans yielded 10.1% more than the LLGT27 and the 76-cm rows had a 10.3% increase in yield compared to the 38-cm rows.

Response of a Putative ALS-resistant Fall Panicum Accession from Wisconsin to Nicosulfuron and Other POST Herbicides. Jose J. Nunes*[1], Alexandre T. Rosa[2], Nicholas J. Arneson[1], Jeff Laufenberg[3], Rodrigo Werle[1]; [1]University of Wisconsin-Madison, Madison, WI, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]Syngenta Crop Protection, Fond Du Lac, WI (113)

POST-emergence grass control in sweet corn production can be a challenge due to the lack of herbicide options. Sweet corn producers typically rely on nicosulfuron as the main effective POST option for grass control. In Wisconsin, a sweet corn producer reported control escapes of fall panicum plants (*Panicum dichotomiflorum* Michx) after spraying nicosulfuron. Therefore seeds of this accession, plus seeds of an accession from a field without nicosulfuron use history, were submitted to fulfill this study's objectives, which were to confirm ALS resistance in the aforementioned fall panicum accession from WI and evaluate its response to alternative POST herbicide options. Two studies were conducted under greenhouse conditions in a CRD (Completely Randomized Design). Each treatment was replicated 6 times and each rep consisted of a cone-tainers (656 ml) filled with Pro-Mix HP Mycorrhizae containing one fall panicum plant. Study 1 consisted of a dose-response to evaluate the response of both accessions to nicosulfuron (rates 0; 3.9; 7.9; 15.9; 31.7; 63.5; 127; and 254 g ai ha^{-1}). Study 2 consisted of a screening to the following herbicides to assess potential options for the control of both accessions. Clethodim (105 g ai ha^{-1}); quizalofop (70 g ae ha^{-1}); glyphosate (864 g ae ha^{-1}); glufosinate (650 g ai ha^{-1}); isoxaflutole (105 g ai ha^{-1}); mesotrione (105 g ai ha^{-1}); and tembotrione (92 g ai ha^{-1}). Application was made when plants reached 10 cm in height using a single-nozzle (AI952EVS nozzle tip) research track spray chamber calibrated to deliver 140 L ha^{-1} of spray solution. At 28DAT, visual efficacy assessment (0 to 100%) and aboveground (green) biomass harvest were performed. The putative ALS-resistant fall panicum accession showed to be highly tolerant to nicosulfuron whereas the ED90 for control (%) and biomass reduction (%) were greater than the highest rate sprayed (>254 g of ai ha^{-1}). The putative ALS-susceptible accession required 58.1 and 57.3 g of ai ha^{-1} of nicosulfuron to achieve such level of control and biomass reduction, respectively. In study 2, regardless of the accession, the level of control and biomass reduction observed were statically similar, with no interactions. Clethodim, quizalofop, and glyphosate were the herbicides with the highest level of control and biomass reduction (100% for all). Even though glufosinate showed a fair level of control (83.5%), and high biomass reduction (98.7%) its efficacy was not consistent, with regrowth observed in some of the plants treated with this herbicide. The HPPD inhibitor herbicides tembotrione, mesotrione, and isoxaflutole did not provide effective control of this species (control of 19.5, 26.0, and 37.5%, respectively). The biomass reduction by these herbicides ranged from 44.5 to 61.3%. Still, by the end of the study, all plants were healthy and could likely produce seed. Molecular studies in collaboration with Dr. Tranel's lab at the University of Illinois are underway to evaluate the potential mechanism of ALS resistance. To our knowledge, this is the first confirmation of ALS resistance in fall panicum in the United States. Keywords: Weed resistance; weed control; *Panicum dichotomiflorum*.

Current Status of Herbicide-Resistant Waterhemp (*Amaranthus tuberculatus*) in Iowa Corn and Soybean Fields. Ryan C. Hamberg*, Prashant Jha, Ramawatar Yadav, Avery J. Bennett, Alexis L. Meadows, Edward S. Dearden, Iththiphonh A. Macvilay; Iowa State University, Ames, IA (114)

Herbicide-resistant waterhemp [*Amaranthus tuberculatus* (Moq.) Sauer] has spread rapidly over the last decade. This is creating a nearly insurmountable problem for corn and soybean producers in the Midwest. With dwindling herbicide resources, there is a need to better understand the current status of herbicide-resistant waterhemp to design effective integrated weed management (IWM) programs. In the fall of 2019, seed samples from >250 populations were collected from growers' fields across Iowa. The objective of this study was to determine both the frequency and distribution of resistance by screening each population with seven different herbicide sites of action including, ALS (imazethapyr), PS II (atrazine), PPO (lactofen), HPPD (mesotrione), EPSPS (glyphosate), and auxinic (2,4-D, and dicamba). The first five herbicides were tested with 1X (field-use rate) and 4X rates, while 2,4-D and dicamba were used at 1/2X and 1X rates. Applications were made inside a cabinet spray chamber calibrated to deliver 187 L ha^{-1} when plants were 5- to 6- cm tall. Percent visible injury (0 to 100%) was recorded at 14, 21 and 28 days after application (DAA) and a binomial response (dead/alive) of plant survival was recorded at 28 DAA. Resistance threshold used in this experiment was 20% survival to the 4X rate and 30% survival to the 1X rate. Results from 70 populations showed that >90% of the populations were resistant to ALS, PS II and EPSPS herbicides at the 4X rates. Resistance to PPO and HPPD herbicides was 12 and 8%, respectively, to the 4X rates. The survival frequency of 2,4-D and dicamba at the field-use rate was 8% and 5%, respectively. All populations tested were at least 2-way multiple herbicide-resistant; >90% were 3-way resistant to ALS, PS II and EPSPS; 25% were 4-way resistant to ALS, PS II, EPSPS and PPO or HPPD. In conclusion, there is apparently an increased occurrence of 3-4 way multiple herbicide-resistant waterhemp populations in Iowa corn and soybean fields, with high levels of evolved resistance to those herbicides. Only one population survived 5 herbicides including 2,4-D. Survivors to the field use rate of 2,4-D and dicamba that produced seeds are current being grown in the greenhouse under pollen isolation conditions to conduct full dose response screening. We will use the data from this survey to compare with the previous survey (2013) and model temporal changes in resistance evolution as impacted by changing management practices. Evident from this survey, there is an urgent need for the implementation of more ecologically based multi-tactic strategies to control waterhemp in corn-soybean production systems of the Midwest.

Foxtail Management in Smooth Brome Hay Meadows. Stewart Duncan*, Sarah Lancaster; Kansas State University, Manhattan, KS (115)

Smooth brome (*Bromus inermus*) is a major hay and pasture crop in eastern Kansas. Growers and County Extension Agents have recently begun to report reduced smooth brome productivity and increased occurrence of foxtail (*Setaria)* species. In order to address these concerns, experiments were established at two on-farm locations to evaluate foxtail control and brome response to selected herbicides applied at two timings in established hay meadows. The primary foxtail species in the hay meadows were yellow foxtail (*S. pumila*) and giant foxtail (*S. faberi*) Herbicides evaluated included metsulfuron, pendimethalin, and *S*-metolachlor applied in spring or after harvest. Foxtail control and smooth brome injury were collected biweekly for approximately eight weeks after each application. Smooth brome dry matter production was determined in early June, immediately prior to meadow harvest. Spring applications of pendimethalin provided excellent control of foxtail initially, but no treatment provided acceptable control throughout the growing season. All herbicide applications resulted in some injury, with metsulfuron causing significant injury when applied in spring that were associated with reduced dry matter yield. Future research should evaluate the potential of split applications of pendimethalin to suppress foxtail germination throughout the growing season.

Waterhemp Control as Affected by Respray Order and Timing Using Single Active Ingredient Applications of Glufosinate, Dicamba, 2,4-D and Glyphosate. Elaina M. Crawford*, Kinsey E. Tiemann, Brent S. Heaton, Mark L. Bernards; Western Illinois University, Macomb, IL (116)

Most herbicide labels recommend application to weeds less than 10 cm tall. However, weather or mechanical issues may cause applications to be delayed past the optimum weed size. Because waterhemp (*Amaranthus tubercalatus)* and marestail (*Conyza canadensis)* have evolved resistance to many herbicides, new technologies (e.g., glufosinate-, dicamba-, and 2,4-D-resistant soybean) have been introduced to provide improved weed control. While the preferred herbicide-resistance management approach is to use effective herbicide mixtures, we wanted to examine the effectiveness of sequential applications of single active-ingredient herbicides on weeds greater than 10 cm tall. Our objective was to determine the optimum interval and sequence using single active ingredient applications of glyphosate, glufosinate, 2,4-D, or dicamba for control of large waterhemp and marestail. The experiment was conducted in Macomb, IL, at Western Illinois University's Kerr Agronomy Farm on a Keomah silt loam. A blend of Asgrow 36X6 and Stine 36EA02 soybeans were planted at 539,000 seeds ha^{-1} on June 5, 2020. The first postemergence application of glufosinate (654 g ae ha^{-1}), 2,4-D (1060 g ae ha^{-1}), or dicamba (560 g ae ha^{-1}) was made on July 2, 2020. Sequential applications of glufosinate or glyphosate following 2,4-D or dicamba, and dicamba, 2,4-D or glyphosate following glufosinate, were made 21 and 28 days after the first application. Visual estimates of weed control were made 21 and 28 days after the final herbicide application was made to each plot, and weed counts and weed biomass were taken from two 0.1 m^{-2} quadrats in each plot at the 28 day rating. Waterhemp control was equal when the sequential herbicide was applied either 21 days (89%) or 28 days (92%) after the initial application. Control of waterhemp was not affected by the sequence of contact (glufosinate) and systemic (dicamba, 2,4-D and glyphosate) herbicides. Waterhemp control when the contact herbicide was applied first was 89%, and when the systemic herbicide was applied first it was 91% at the 28 day rating. All sequential herbicide treatments provided greater suppression of waterhemp density and biomass compared to single applications of glufosinate, dicamba, or 2,4-D. Our data support the best management practice of applying a synthetic auxin herbicide early in the season when temperatures are cooler, followed by glufosinate when temperatures are warmer for control of glyphosate-resistant populations of waterhemp and marestail.

Weed Control in and Yield of Soybean Planted into Green Rye Treated with Supplemental Nitrogen. Kinsey E. Tiemann*, Brent S. Heaton, Joel Gruver, Mark L. Bernards; Western Illinois University, Macomb, IL (117)

The use of cover crops has become increasingly important for weed and nutrient management in corn (*Zea mays*) and soybean (*Glycine max*) cropping systems. The termination time of rye (*Secale cereale*) relative to soybean planting influences the suppression of weeds – later termination and more biomass generally provides greater suppression. Planting soybean into green cover crops sometimes causes yield loss, possibly because nitrogen is sequestered in the cover crop. 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 control and soybean yield as affected by cereal rye termination time and the addition of supplemental nitrogen at planting. The factorial study included three termination times: 2 weeks before planting, or 0 or 2 weeks after planting and four nitrogen rates: 0, 22, 44, or 66 kg N ha^{-1} applied at planting. Soybean variety 'S33-E3' planted May 25, 2020 at 342,000 seeds ha^{-1}. In the first study, no residual herbicide was applied so the effect of rye on weed emergence and growth could be measured. At 2, 4, and 6 weeks after planting, weed counts were recorded from three marked 0.1 m^2 quadrats in each plot, and weed biomass was collected from two other 0.1 m^2 quadrats. In the second study, residual herbicides were applied at rye termination to maintain the plot area weed free. Soybean stand, height, and biomass measurements were collected 2, 4, and 6 weeks after planting, and following crop senescence, each plot was harvested for yield. Nitrogen rate had no effect on weed counts, weed biomass, soybean growth or yield. Delaying rye termination until 2 weeks after plantings reduced weed density and biomass, but also reduced early season soybean growth and yield. Terminating the cover crop at the time of planting did not affect yield, but did reduce weed biomass when compared with terminating the cover crop 2 weeks before planting.

Interaction of Tank-mixtures of Glyphosate and Dicamba on Glyphosate-resistant Horseweed Control. Leandro H S Guimaraes*[1], Estefania Gomiero Polli[1], Jose H. Scarparo de Sanctis[2], Guilherme Sousa Alves[1], Greg R. Kruger[1]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Nebraska-Lincoln, Lincoln, NE (118)

Dicamba/glyphosate-resistant (DGR) soybean became available in the 2017 growing season, since then growers have largely adopted this new technology. Consequently, dicamba plus glyphosate applications became a common tank mixture combination for broad-spectrum weed control. However, the effect of dicamba plus glyphosate tank mixtures on weed control is not clearly understood. Previous literature suggests that interactions between those herbicides might be species-specific. This study was elaborated to further investigate the interaction of dicamba plus glyphosate tank-mixtures on glyphosate-resistant (GR) horseweed (*Erigeron canadensis* L.) population. Greenhouse experiments were conducted at the Pesticide Application Technology Laboratory in North Platte, NE during 2020. Herbicide treatment consisted on combinations of dicamba at 0, 140, 280, 560, 840, and 1120 g ae ha^{-1} and glyphosate at 0, 316, 630, 1260, 1900, and 2530 g ae ha^{-1}, using a TTI11002 nozzle delivering 140 L.ha^{-1} in a triple nozzle spray chamber. The experiment was conducted in a split-plot design with four replications. At 28 days after treatment (DAT) above-ground biomass was harvested and oven-dried at 65 C until constant weight. Dose-response curves behaved as expected, with increasing biomass reduction as glyphosate and dicamba rates increased. Dicamba at 1020 g ae ha^{-1} combined with glyphosate at 2520 g ae ha^{-1} provided the highest biomass reduction at 90%. Colby correlation table demonstrated an antagonistic relation between dicamba and glyphosate throughout the entire range of herbicide doses. Glyphosate at 1260 g ae ha^{-1} and dicamba at 560 g ae ha^{-1} resulted in 73% and 76% biomass reduction, respectively. Expected biomass reduction for the combined dicamba and glyphosate tank-mix with the aforementioned rates was 93%; however, the observed biomass reduction was 77%.

Stubble Height Does Not Influence Weed Suppression by Triticale. Tyler P. Meyeres*, Malynda M. Smith, Sarah Lancaster; Kansas State University, Manhattan, KS (119)

Cover crops are often used as part of an integrated weed management program. The primary mechanism by which cover crops suppress weeds is through abundant biomass production. To improve the profitability of systems using cover crops, farmers may graze or otherwise harvest plant biomass before terminating the cover crop at planting. A study was conducted at Ottawa Kansas to determine the effect of biomass removal on weed suppression by triticale and weed control by pre-emergence herbicide applications. Triticale was drilled at 67 kg ha^{-1} during November 2019. During June, 2020 treatments were applied in a split plot arrangement with a main plot of cover crop stubble height (10 cm, 20 cm, 30 cm or no removal) and subplots of herbicide treatment (418 g ai ha^{-1} sulfentrazone + 26 g ai ha^{-1} chlorimuron + 1542 g ai ha^{-1} glyphosate + 1906 g ai ha^{-1} ammonium sulfate, 196 g ai ha^{-1} sulfentrazone + 1766 g ai ha^{-1} s-metolachlor + 1542 g ai ha^{-1} glyphosate + 1906 g ai ha^{-1} ammonium sulfate, or no herbicide). An additional herbicide application of 568 g ai ha^{-1} bentazon + 280 g ai ha^{-1} acifluorfen + 2103 ml ha^{-1} non-ionic surfactant was made in late June to control glyphosate-resistant waterhemp. Visual weed control was assessed 2, 4, and 8 weeks after planting. Data were subjected to analysis of variance with replicate as a random variable and means separation using Tukey's pairwise comparisons (a=0.05) using the lmer package in R. The interaction of triticale stubble height and herbicide was not a significant, nor was the main effect of stubble height. Both herbicides provided similar weed control at all evaluation times. This experiment suggests that biomass removal immediately prior to termination will not affect weed suppression by cover crops. However, additional research should evaluate the effect of winter grazing on weed suppression.

Impact of Soil Management Practices on the Persistence of S-metolachlor and Sulfentrazone. Kolby Grint*[1], Rodrigo Werle[2], Nicholas J. Arneson[2], Daniel H. Smith[2], Ryan P. DeWerff[2]; [1]University of Wisconsin-Madison Agronomy Department, Madison, WI, [2]University of Wisconsin-Madison, Madison, WI (120)

Application of preemergence (PRE) herbicides with soil residual activity has become a standard recommendation for the management of troublesome weeds that have evolved resistance to commonly used postemergence herbicides in corn (*Zea mays*) and soybean (*Glycine max*) production systems. Widespread use of these herbicides has led to concerns over potential environmental contamination and injury to non-target organisms. In the Summer of 2019 and 2020, field experiments were established at two Wisconsin locations to investigate the potential of different soil management practices in a corn-soybean rotation to influence the soil persistence of PRE herbicides. Treatments consisted of five soil management practices (conventional tillage, no-till, and a fall-seeded cereal rye [*Secale cereale*] cover crop terminated two weeks prior to crop planting, at the time of crop planting, and two weeks after crop planting) and two commonly used pre-emergence herbicide mixes applied immediately after crop planting. S-metolachlor persistence was measured in the corn and sulfentrazone was measured in the soybean phases of the studies. The concentration of herbicides 30 days after application varied across site-years. Soil concentration of S-metolachlor and sulfentrazone was greater in soil managed with conventional tillage compared to soil managed with conservation practices (no-till and cover crops). Using soil conservation practices reduced the concentration of both S-metolachlor and sulfentrazone in soil one month after application, which could reduce their potential negative impacts to non-target organisms from prolonged persistence. Understanding the influence that soil management practices have on persistence of residual herbicides can help applicators mitigate potential environmental contamination and harm to non-target organisms due to prolonged persistence of these herbicides in soil.

Evaluation of Putative Resistance in Wisconsin Giant Ragweed (*Ambrosia trifida*) to Group 2, 9, and 14 Herbicides. Felipe A. Faleco*, David E. Stoltenberg, Rodrigo Werle; University of Wisconsin-Madison, Madison, WI (121)

Giant ragweed (*Ambrosia trifida*) has become one the most difficult weeds to manage in row crops in the U.S. Corn Belt. ALS- and EPSPS-inhibitor resistance in giant ragweed have been confirmed in 7 and 12 states in the U.S., respectively, including Wisconsin. However, a comprehensive investigation of herbicide resistance status in giant ragweed across Wisconsin cropping systems is lacking. Therefore, our objective was to evaluate putative resistance of giant ragweed populations from Wisconsin to cloransulam (ALS-inhibitor), glyphosate (EPSPS-inhibitor), and fomesafen (PPO-inhibitor) herbicides applied POST emergence, hypothesizing that cloransulam and glyphosate resistance are present in the populations evaluated while fomesafen resistance is not. Seed samples from 9 giant ragweed populations were collected and submitted by Wisconsin stakeholders in the fall of 2018 (five of them collected from non-GMO soybean fields). One additional glyphosate-susceptible population was included for comparisons. The greenhouse study was conducted in a RCBD with two experimental runs. Treatments were sprayed in a single-nozzle spray chamber, 140 L ha^{-1} spray volume for all applications. Herbicide treatments consisted of cloransulam (1x = 17.64 g ai ha^{-1} + 0.6 v/v % HSOC + 1428 g ha^{-1} AMS), glyphosate (1x = 864 g ae ha^{-1} + 1428 g ha^{-1} AMS), and fomesafen (1x = 263 g ai ha^{-1} + 0.5 v/v % HSOC + 1428 g ha^{-1} AMS) at 1x and 3x the label rate, plus a NTC for each population. Treatments were sprayed when plants reached 5 to 10 cm in height. At 21 DAT, visual evaluation (VE) was taken on a scale from 1 (dead plant) to 10 (healthy plant) and biomass collected. Populations with 50% = of treated plants with VE = 7 were classified putative-resistant to the treatment of interest. According to our results, 33% and 22% of giant ragweed populations were classified putative-resistant to 1x cloransulam and glyphosate, respectively. Glyphosate non-rapid response (NRR) phenotype was observed. A putative fomesafen-resistant giant ragweed population was detected (Rock County, WI) and will be further investigated. Currently, ALS and PPO-inhibitors herbicides are the main options for POST giant ragweed control in non-GMO soybeans. If resistance to these herbicides is present, POST giant ragweed chemical control becomes very difficult particularly in this system.

Using Multi-Tactic Strategies to Manage Herbicide-Resistant Waterhemp in Corn-Soybean Rotations of the Midwest. Ramawatar Yadav*, Prashant Jha, Damian D. Franzenburg, Iththiphonh A. Macvilay, Ryan C. Hamberg, Avery J. Bennett, Edward S. Dearden, Alexis L. Meadows; Iowa State University, Ames, IA (122)

Common waterhemp [*Amaranthus tuberculatus* (Moq.) J. D. Sauer] populations resistant to seven different herbicide groups have been reported in the Midwest. This has critically reduced viable herbicide options to control this species in corn-soybean rotations. Therefore, there is an immediate need to develop ecologically based, integrated weed management (IWM) strategies at a cropping systems level. Field experiments were conducted during summer 2019 to fall 2020 to fulfill the aforementioned objective in a corn-soybean rotation at two sites; the Iowa State University Research Farms in Ames, IA and in Boone, IA. A three factor split-split plot design was used with four replications. The whole plot factor comprising of three levels of weed seed bank inputs [marginal (two site-of-action herbicide), aggressive (three sites-of-action herbicides), and aggressive (three sites-of-action herbicides plus weed seed removal at-harvest) programs] was established in 2019 in corn. The subplot factor implemented in the soybean phase of the rotation included cereal rye cover crop vs. no cover crop. Cereal rye (var. Elbon) was drill-seeded (67 kg ha^{-1}) in the fall of 2019 on corn stubble and terminated (~4700 kg ha^{-1} biomass) using glyphosate at the time of soybean planting in the spring of 2020. The sub-subplot factor was established by planting soybean in 38 vs. 76-cm rows. The marginal herbicide program (MHP) provided =35% waterhemp control and produced >90,000 seeds m^{-2} in the corn phase. In contrast, the aggressive herbicide program (AHP) provided =90% waterhemp control and produced ~9000 seeds m^{-2}. These seeds were hand-removed to create AHP plus weed seed removal treatment (no seed input). In the absence of cereal rye cover crop and narrow rows, AHP plus weed seed removal in corn reduced waterhemp density by >35% and >70% in soybean compared with AHP (no weed seed removal) and MHP, respectively. This emphasizes the need of an effective and diversified weed control program in corn to reduce weed seed inputs in the following soybean crop. Even with a MHP in corn, cover crop and 38-cm rows were effective in reducing waterhemp density by >40% compared with no cover crop and 76-cm soybean rows. Sub subplots with AHP plus weed seed removal, presence of cover crop, and 38-cm rows (most diverse system) reduced waterhemp density and seed production by >85% compared with plots that had MHP, no cover crop, and 76-cm soybean rows (least diverse system). These results indicate that cultural strategies such as cereal rye cover crop and reduced row spacing should be incorporated into current IWM programs to effectively manage HR waterhemp seed banks in corn-soybean rotations.

Physical Mapping of Amplified Copies of *EPSPS* Gene in Glyphosate-resistant *Bromus diandrus*. Sathishraj Rajendran*[1], Dal-Hoe Koo[1], Christopher Preston[2], Mithila Jugulam[1]; [1]Kansas State University, Manhattan, KS, [2]University of Adelaide, Adelaide, Australia (123)

Bromus diandrus (2n =56) is an annual weed of cereal crops and pastures across the southern Australia in some parts of the US. The extensive use of glyphosate resulted in the evolution of resistance to this herbicide in *B. diandrus* in Australia. Amplification of EPSPS gene, the molecular target of glyphosate, was found to confer resistance to glyphosate in *B. diandrus*. The objective of the present investigation was, using molecular cytogenetics technique, i.e., fluorescence *in situ* hybridization (FISH), to map the amplified copies of *EPSPS* in the genome of glyphosate-resistant (BdSA988R) in comparison with glyphosate-susceptible (BdS) *B diandrus* The *EPSPS* copy number BdSA988R and BdS *B diandrus* population was determined by SYBER green based qPCR assay. The susceptible population had copy number ranging from 0.6 - 1.0 whereas, the resistant population had 6 to 9 copies. The FISH probe for *EPSPS* gene was prepared using genomic DNA of *B. diandrus.* FISH analysis was performed on mitotic chromosme spread from root tip cells. In the BdS plants, faint hybridization signals for *EPSPS* gene were found on two homologous chromosomes, at the telomere position. In contrast, BdSA988R plants showed much brighter hybridization signals of *EPSPS* gene, yet at the telomere of a pair of homologous chromosomes, suggesting an increase in *EPSPS* gene copies at this position in resistant plants. The telomere region of the chromosomes are known to be a hotspot for recombination and crossover events. These results suggest that unequal crossing over at the telomere region may have caused the initial *EPSPS* gene duplication event and under increased glyphosate selection and subsequent meiotic events resulted in increase in *EPSPS* copy number; providing resistance to glyphosate in *B. diandrus*.

Role Reversal: Glufosinate Control of Suspected Glyphosate-Resistant Johnsongrass (*Sorghum halepense*) in XtendFlex® Soybean. Sarah E. Dixon*[1], Neha Rana[2], Justin Pollard[3], Reid J. Smeda[1]; [1]University of Missouri, Columbia, MO, [2]Bayer Crop Science, St Louis, MO, [3]Bayer Crop Science, Camden Point, MO (124)

A new biotype of glyphosate-resistant Johnsongrass (*Sorghum halepense*) has been identified in agronomic fields in northwest Missouri. At two sites in 2020, glyphosate-resistant Johnsongrass was a target weed species for evaluation of mid-season POST grass control options in XtendFlex® soybean. Each site was under different tillage regimes: conventional tillage (CT) and no-till (NT). Soybeans (4020RXF) were planted on May 19, 2020 at 408,000 seeds ha^{-1} in 76 cm rows at two sites in Missouri. All plots (3x3 m), excluding untreated controls, received an early POST application of dicamba (562 g ha^{-1}), glyphosate (1263 g ha^{-1}) and acetochlor (1259 g ha^{-1}) on June 8. Both experiments contained six treatments in addition to an untreated control: glufosinate (655 g ha^{-1}) plus glyphosate (1263 g ha^{-1}); glufosinate alone (655 g ha^{-1}); glyphosate alone (1263 g ha^{-1}); clethodim (140 g ha^{-1}); fluazifop-P-butyl (210 g ha^{-1}); and fluazifop-P-butyl (210 g ha^{-1}) plus fenoxaprop-P-ethyl (59 g ha^{-1}). Mid-season POST treatments were applied on June 23 using a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1}. Evaluations included weekly estimates of visual weed control (0-100; 0=no injury and 100=dead); weed density per 0.5 m^2; and surviving grass weed biomass per plot (cut at the soil line and dried at 50? for 72 h). Results from one year of data suggest that absent the typical response to glyphosate, Johnsongrass responds to glufosinate and Group 1 herbicides applied mid-season. The data suggest that the dominant weed in the no-till site was glyphosate-resistant Johnsongrass. In the site with conventional tillage, Johnsongrass pressure was unevenly distributed, with evidence for the presence of both susceptible and resistant Johnsongrass in addition to giant foxtail (*Setaria faberi*) and green foxtail (*Setaria viridis*). Surviving weed biomass was highest with glyphosate alone in both sites, with 25 and 49 g per $0.5m^2$ for CT and NT, respectively. In the no-till site, Johnsongrass response to glufosinate plus glyphosate was not different than glufosinate alone. Treatments containing glufosinate resulted in up to 99% less weed biomass than glyphosate alone. Group 1 herbicides outperformed glufosinate across all evaluations with up to 99% control by visual injury and mean 0.7 g surviving weed biomass per $0.5m^2$. However, no significant differences between glufosinate and Group 1 treatments were observed in the site with conventional tillage. While glufosinate alone will not control Johnsongrass infestations, glufosinate control of seedling Johnsongrass can be considered as part of a broader management strategy for growers with suspected glyphosate-resistant Johnsongrass.

Weed Seed Dynamics in an Interseeded System of Corn Silage and Alfalfa. Sarah A. Chu*, Erin E. Burns; Michigan State University, East Lansing, MI (125)

Interseeding alfalfa (*Medicago sativa*) and corn silage (*Zea mays*) may increase alfalfa acres that are decreasing in Michigan due to reliance on corn silage as a continual feed source. In addition to environmental benefits including season long living ground cover provided from interseeding, there is potential to use this system for weed control by increasing interspecific competition. Therefore, the objective of this study was to assess weed seed production, germinability, viability, and population dynamics in an alfalfa corn silage interseeded system. A two-year field study was conducted in East Lansing, MI in 2019-2020. The study followed a randomized complete block design with four replications. Whole plots were assigned to one of two corn silage hybrids with different leaf architecture, pendulum (wide leaf angle) or upright (narrow leaf angle) to assess impacts of light penetration on weed dynamics. Subplots were assigned to one of eight weed removal or addition timings. Control treatments were kept weed free and weedy. Glyphosate tolerant alfalfa variety was planted on the same day as the corn. To establish uniform densities and emergence a surrogate weed, Japanese millet (*Echinochloa esculenta*), was used. Japanese millet seed production was collected at the end of the season and viability assessed using tetrazolium testing. The following year soil samples were collected to assess overwinter seed survival. Data were analyzed using linear mixed effect models in R. Differences in means were further investigated using Tukey's HSD. Demographic data was used to create a stochastic density dependent population dynamics model in R to evaluate long-term impacts of interseeding on weed populations. Japanese millet seed production was statistically significant between years ($p<0.001$); therefore, years were analyzed separately. In 2019, there was no difference in millet seed production between the two hybrids ($p=0.7$) or interseeded vs. monoculture corn weedy treatments($p=0.14$). There was no difference between weed addition/removal timings in 2020 ($p=0.5$). However, in 2020, seed production decreased in the pendulum hybrid by 68% compared to the upright hybrid ($p=0.04$). Seed viability was not significantly different between year ($p=0.85$) and hybrid ($p=0.3$) therefore years were combined for analysis. Interseeded corn-alfalfa decreased weed seed viability by 46% compared to monoculture corn plots average across hybrids ($p=0.02$). In the population growth model based on 2019 data, the interseed treatment with the pendulum hybrid resulted in growth rates equal to 1 indicating stable growth. The interseeded treatment of the pendulum hybrid decreased population growth by 49% compared to the monoculture treatments. There were no differences in population growth rate between the interseeded treatments regardless of hybrid. The seed model based on 2019 data interseeded treatment decreased seeds present by 99% in both the pendulum and upright hybrids. Data based on 2020 resulted in a crashing seed and population model due to the lack of precipitation during the establishment of Japanese millet. Interseeding can offer environmental and economic benefits but can also provide weed management.

Crop Canopy Development Influences Waterhemp *(A. tuberculatus)* Growth. Nikola Arsenijevic*[1], Nicholas J. Arneson[2], Maxwel Coura Oliveira[2], Rodrigo Werle[2]; [1]Universtiy of Wisconsin-Madison, Madison, WI, [2]University of Wisconsin-Madison, Madison, WI (126)

Waterhemp (*Amaranthus tuberculatus* Moq.) is a problematic weed species in cropping systems throughout Wisconsin and much of the North Central region Waterhemp has evolved resistance to multiple SOA's, thus becoming more difficult to control through chemical-based weed management programs. Early-season weed control is crucial in order to minimize competition with crop and ultimately prevent yield loss. The objective of this study was to evaluate the impact of soybean and corn crop canopy on suppression of waterhemp growth. A field experiment was conducted in 2019 and 2020 at Arlington Agricultural Research Station, WI. Treatments consisted of narrow (0.38 m) and wide-rowed (0.76 m) soybeans, corn (0.76 m), and fallow area. Treatments were replicated four times and organized in a randomized complete block design. Waterhemp seedlings grown in the greenhouse were transplanted at the 2-3 true leaves growth stage to the study area at 10-day increments throughout the typical waterhemp emergence season for Wisconsin. Seedlings were transplanted between rows (2^{nd} and 3^{rd} for wide soybeans and corn, and 3^{rd} and 4^{th} for narrow soybeans). Waterhemp plants were harvested for biomass when they reached the flowering stage. Date, height, treatment, and sex of waterhemp plants were recorded at the time of harvest. The results from this experiment indicate that corn, narrow and wide-row soybean crop canopy reduced the biomass of transplanted waterhemp plants at each transplanting timing similarly when compared to the fallow treatment, with the greatest waterhemp biomass reduction for the later cohorts. The narrow-row soybeans had the highest impact on waterhemp height, followed by corn and wide-rowed soybeans, with impact increasing when seedlings were transplanted later in the season. Rapid canopy closure combined with other integrated weed management practices have the potential to reduce reliance on herbicides and slow down herbicide resistance evolution.

The Development of Ames 25286: a Herbicide Sensitive Reference Population for *Amaranthus tuberculatus*. Brent P. Murphy*, Patrick Tranel; University of Illinois, Urbana, IL (127)

Waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer) is a predominant driver weed species throughout annual production systems in the American Midwest. Notably, herbicide resistance evolution and spread has become increasingly problematic for weed management. The characterization of herbicide resistance through greenhouse experiments is dependent on the reliability of a sensitive reference population. Furthermore, as Omics approaches are increasingly adopted for the identification and validation of resistance mechanisms, a sensitive reference population can provide a focus for reference resource development. We propose the use of Ames 35286, a publicly available sensitive reference population derived from the uniformly sensitive WUS population, which originated from a riparian population in Ohio. Ames 35286 was developed through a single paired cross of plants selected for sensitivity to tembotrione, and propagated to the pseudo-F_2 generation. Parent plants were subjected to a resequencing pipeline, identifying over 16M sequence variants compared to the v1 reference genome. Dose-response experiments are underway for representative herbicides from Group 2, 3, 4, 5-7, 9, 10, 14, and 27 to quantify sensitivity to these herbicides. Germplasm is publicly available through the NPGS GRIN-GLOBAL system: https://npgsweb.ars-grin.gov/gringlobal/accessiondetail?id=2099571.

Field Pennycress (*Thlaspi arvense*) Response to Simulated Carryover of Group 27 Herbicides in the Greenhouse. Daniela R. McConnville*[1], Claudia R. Bland[2], Brent S. Heaton[1], Mark L. Bernards[1]; [1]Western Illinois University, Macomb, IL, [2]Purdue University, West Lafayette, IN (128)

Pennycress (*Thlaspi arvense*) is being domesticated as an oilseed crop. Plant breeders have occasionally observed injury from Group 27 herbicide carryover. Greenhouse dose-response studies based on herbicide half-life can provide useful data on pennycress sensitivity to herbicides that may persist from the previous crop. Our objective was to evaluate pennycress stand establishment as affected by simulated herbicide carryover from single active ingredient Group 27 herbicides. A dose response experiment was conducted in the Spring and repeated in the Fall of 2020 at Western Illinois University's School of Agriculture Greenhouse in Macomb, IL. An Ipava silt loam soil was modified at 4 parts soil, 1-part perlite, and 1-part sand. Approximately 15 seeds of pennycress variety 'ARV1' were planted in each 10 x 10 cm pot and watered immediately prior to herbicide application. Five doses of nine corn herbicides (mesotrione, tembotrione, isoxaflutole, topramezone, tolpyralate, atrazine, safulfenacil, rimsulfuron, and thiencarbazone-methyl) simulating doses equivalent to 2 to 6 half-life periods (based on maximum-labeled use rates) were sprayed in a single-tip chamber sprayer at an application volume of 180 L ha^{-1}. Stand counts and visual estimations of chlorosis and necrosis were made 21 days (~3 weeks) after initial spray application was made. Pennycress stand counts increased as herbicide dose decreased for mesotrione, tembotrione, isoxaflutole, topramezone, safulfenacil, rimsulfuron, and atrazine, but was relatively unaffected at the doses of tolpyralate, thiencarbazone-methyl tested. Pennycress stand equaled that of the untreated check (6.5 plants pot^{-1}) when herbicide dose of Group 27 herbicides was less than or equal to the concentration expected after 4 half-life periods (0.06x labeled rate or less). Based on half-life intervals of Group 27 herbicides (approximately 15 days) and herbicide application time in corn (no later than early June), herbicide carryover injury in pennycress planted in September or later should be rare.

Field Pennycress (*Thlaspi arvense*) Population and Growth Following Corn Treated with Group 27 Herbicides. Jacob W. Johnson*, Brent S. Heaton, Mark L. Bernards; Western Illinois University, Macomb, IL (129)

Field pennycress (*Thlaspi arvense*) is being domesticated as an oilseed crop to produce biofuel for the airline industry. Pennycress will be planted in the fall following corn (*Zea mays*) and harvested in mid-May before soybean (*Glycine max*) planting. Pennycress is a small-seeded weed and there is concern that carryover of residual corn herbicides may inhibit fall stand establishment, but published data are lacking regarding safe replant intervals for pennycress following the use of residual corn herbicides. Our objective was to evaluate the pennycress sensitivity to herbicide carryover from the previous corn crop. Two experiments were conducted on a Greenbush silt loam at the WIU Agricultural Field Laboratory's Agronomy Farm. Preemergence herbicides (atrazine, mesotrione, isoxaflutole, pyroxasulfone, isoxaflutole+thiencarbazone-methyl, saflufenacil+dimethenamid, mesotrione+S-metolachlor+atrazine+bicyclopyrone) were applied June 6, 2020, and postemergence (tembotrione, topramezone, tembotrione+thiencarbazone-methyl, mesotrione+glyphosate+S-metolachlor) herbicides were applied June 15, 2020 using a backpack sprayer. Single- and multiple-a.i. herbicides were applied at 1X and 2X labeled rates. PRE/POST treatments and herbicides in the Atrazine Tank-mixture study were applied at 2X rates only. Corn was harvested for silage on Oct 6, and pennycress variety 'MN-106' was no-till planted with a John Deere 750 drill (19-cm row spacing) at 2.8 kg ha^{-1} on October 8, 2020. Pennycress stand counts were recorded on November 4, 2020 by counting four 30-cm lengths of row. Pennycress stand was not reduced by planting into plots treated with residual herbicides. In particular, pennycress stand was equal when herbicides were applied at 1x and 2x labeled rates, and pennycress stand was not reduced when supplemental atrazine was applied with Group 27 herbicides. Based on these results and results from a preliminary study, residual herbicides applied in the spring will likely have limited effect on pennycress planted in the fall, provided conditions are favorable for herbicide degradation at normal half-life intervals.

Resistance Fighter: Local Partnerships Drive Better Herbicide Recommendations. Marshall Hay*[1], Peter Eure[2], Ethan T. Parker[1], Dane L. Bowers[3]; [1]Syngenta Crop Protection, Vero Beach, FL, [2]Syngenta Crop Protections, Greensboro, NC, [3]Syngenta Crop Protection, Greensboro, NC (130)

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

Field Pennycress (*Thlaspi arvense*) Response to Simulated Carryover of Group 15 Herbicides in the Greenhouse. Nathan L. Stufflebeam*[1], Mason R. Blickenstaff[1], Claudia R. Bland[2], Brent S. Heaton[1], Mark L. Bernards[1]; [1]Western Illinois University, Macomb, IL, [2]Purdue University, West Lafayette, IN (131)

Field pennycress is being developed as an oilseed cover crop to be grown after corn and before soybean. Herbicides used in corn may negatively affect field pennycress production, and there is a lack of data on herbicide carryover for pennycress stand establishment. Dose response studies may be used to simulate herbicide degradation in the soil, and identify herbicide levels that will not negatively impact a subsequent cover crop. Our objective was to determine field pennycress sensitivity to Group 15 and Group 4 herbicide carryover using simulated half-life doses. A dose response experiment was conducted in the Spring and repeated in the Fall of 2020 in Western Illinois University's School of Agriculture Greenhouse. An Ipava silt loam soil was modified at 4 parts soil, 1-part perlite, and 1-part sand. Approximately 15 seeds of pennycress variety 'ARV1' were planted in 10x10 cm pot and watered immediately prior to herbicide application. Five doses S-metolachlor, acetochlor, pyroxasulfone, dimethenamid, clopyralid, dicamba and 2,4-D were applied to simulate expected herbicide concentrations following 2 to 6 half-life periods for Group 15 herbicides, and 3 to 7 half-life periods for Group 4 herbicides (assuming herbicides are applied at the full-labeled rate). The experiment was arranged as a randomized complete block design with six replications. Stand counts and visual estimations of chlorosis and necrosis were made 21 days (~3 weeks) after initial spray application was made. Pennycress stand increased as herbicide dose decreased (i.e., as half-life period increased) for all four Group 15 herbicides. Pyroxasulfone most negatively affected pennycress stand, and even at 6 half-life period equivalent concentrations, plant counts were less than the untreated control. Clopyralid and dicamba did not affect pennycress stand at doses equal to 3 or more half-life periods, but pennycress counts did increase as 2,4-D dose decreased. Based on a typical application time of Group 15 herbicides (no later than early June in corn) and pennycress planting (after September 1), herbicide concentrations will likely be 1/8th to 1/32nd of the applied dose (3 to 5 half-life periods), and will likely cause minimal stand loss, with the possible exception of pyroxasulfone.

The Effect of Trifludimoxazin on the Frequency of the ΔG210 Target Site Mutation in Field Populations of Waterhemp. Jesse A. Haarmann*[1], Bryan G. Young[2], William G. Johnson[1]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, Brookston, IN (133)

The PPO-inhibiting herbicides remain important components of waterhemp (*Amaranthus tuberculatus* (Moq.) J. D. Sauer) management in soybean. When applied PRE, PPO-inhibiting herbicides are partially effective on resistant waterhemp at the cost of reduced length of residual activity and a greater frequency of PPO inhibitor resistance in the surviving waterhemp plants. Trifludimoxazin is a PPO-inhibiting herbicide currently under development that has soil and foliar activity and has been documented to control group 14-resistant waterhemp (**Δ** G210 and R128G) and Palmer amaranth (*Amaranthus palmeri* S. Watson) (**Δ** G210) in foliar applications. Control of such resistant biotypes is attributed to unique binding properties of trifludimoxazin to the PPX2 enzyme. Soybean tolerance to trifludimoxazin is achieved with soil applications (PRE), yet the efficacy of trifludimoxazin on PPO inhibitor-resistant Amaranthus has not been reported. Our objective was to determine if applications of trifludimoxazin select for PPO-inhibitor resistant individuals when applied PRE similarly to other PPO inhibitors and determine if combinations of trifludimoxazin with other PPO inhibitors can reduce selection for PPO-inhibitor resistant individuals. Our hypothesis was that trifludimoxazin would not select for a greater frequency of **Δ**G210 carrying individuals and that trifludimoxazin combinations with other PPO inhibitors would not reduce selection for **Δ**G210 carrying individuals. Field experiments in 2020 at two Indiana locations were conducted where trifludimoxazin, saflufenacil, and fomesafen were applied PRE in soybean 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. Weed control ratings were recorded and tissue from the first 25 emerged plants in each plot were collected for DNA extraction and subsequent qPCR assays for the **Δ** G210 mutation. Sparse rainfall during early soybean growth stages resulted in exceptionally long residual activity. By 28 days after treatment, control from all herbicide treatments except trifludimoxazin alone was at least 92%. Combinations of trifludimoxazin+fomesafen, saflufenacil+fomesafen, and trifludimoxazin+saflufenacil+fomesafen provided 96 to 98% control of waterhemp 35 days after treatment which was greater than trifludimoxazin and saflufenacil alone by 44 to 46% and 13 to 15%, respectively. The average frequency of **Δ** G210 carrying individuals at the two field locations was 25% in the absence of herbicide selection. Trifludimoxazin resulted in a very similar frequency of **Δ** G210 as the no herbicide control (25%) whereas fomesafen and saflufenacil increased the frequency of **Δ** G210 waterhemp plants to 40 and 41%, respectively. Combinations of trifludimoxazin with the other PPO inhibitors did not reduce selection for the **Δ** G210 mutation in comparison to fomesafen or saflufenacil alone with 35 to 44% of individuals carrying the mutation. 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 in soybean. We conclude that trifludimoxazin applied alone is effective for control and management of PPO inhibitor resistant waterhemp; however, future research is justified to determine if trifludimoxazin selects for other mutations or mechanisms of resistance related to the PPO enzyme.

Resistance to S-metolachlor in HPPD-resistant Palmer Amaranth from Nebraska. Carlos Alberto G. Rigon*[1], Anita Küpper[2], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Bayer Crop Science, Frankfurt, Germany (134)

S-metolachlor is a selective and pre-emergent herbicide that inhibits very-long-chain fatty acid elongase (VLCFAE, Group 15). It is commonly used to control most annual grasses and certain broadleaf weeds in various crops. Few cases of resistance to *S*-metolachlor have been identified to date, with most being metabolism-based. A Palmer amaranth (*Amaranthus palmeri* S.) population from Nebraska (NER) was identified to be resistant to the HPPD inhibitor tembotrione due to enhanced metabolism. We hypothesize that NER may be cross-resistance to *S*-metolachlor due to its metabolic profile, the unpredictable cross-resistance potential of metabolism-based resistance mechanism, and the capacity of some plants to metabolize *S*-metolachlor. The objective of the study was to investigate the susceptibility to *S*-metolachlor in this HPPD-resistant population NER. A dose-response experiment was performed using two susceptible Palmer amaranth populations as controls, one from Eastern Colorado (ECS), and one from Nebraska (NES), as well as NER. Plants were treated with 0, 2, 4, 8, 16, 33, 66, 133, 266, 532, 1,064 and 2,028 g ha^{-1} *S*-metolachlor. Seeds from each population were germinated in agar. When the radicle emerged (2 d), twelve germinated seeds were transferred into pots containing weighted soil and covered with a thin layer of soil. Each pot was considered an experimental unit, with four replicates. Treatments were applied as PRE-emergent using a spray chamber calibrated to delivery 187 L ha^{-1}. The experiment was repeated twice. Plant survival (% of untreated control) and fresh shoot weight (% of untreated control) were evaluated 28 d after herbicide application. Based on survival, NES and ECS showed high susceptibility to *S*-metolachlor, with an ED_{50} of 33 and 17 g ha^{-1}, respectively, while NER showed an ED_{50} of 181 g ha^{-1}. The fresh weight showed similar results, where the susceptible NES (92 g ha^{-1}) and ECS (90 g ha^{-1}) showed the reduction of 50% of shoot growth at lower dose rates than NER (257 g ha^{-1}). All three populations were 95% controlled using the field rate (1,064 g ha^{-1}), although NER showed to have a lower susceptibility to *S*-metolachlor. NER was 5.4- to 10.6- and 2.7- to 2.8-times more resistant to *S*-metolachlor compared to the susceptible population based on survival and fresh weight, respectively. The enhanced capacity of NER to metabolize HPPD, and the absence of any history of selection pressure with *S*-metolachlor application in the field where NER was collected, indicates that the moderate resistance to *S*-metolachlor that NER is evolving may be metabolism-based. Future work will include studies of gene expression and glutathione-S-transferase activity to better understand the mechanism of resistance. An HPPD-resistant population of Palmer amaranth from Nebraska showed low susceptibility to *S*-metolachlor. The enhanced metabolism profile of this population may favor the deactivation of *S*-metolachlor, but further studies need to be done to test the new hypothesis.

Effect of Increased Temperature on Lactofen Efficacy on PPO-Inhibitor-Resistant and -Susceptible Palmer Amaranth. Ednaldo A. Borgato*, Sathishraj Rajendran, Anita Dille, Mithila Jugulam; Kansas State University, Manhattan, KS (135)

Palmer amaranth (*Amaranthus palmeri*) has a wide window of emergence throughout the cropping season, requiring multiple herbicide applications to maximize control and reduce seed production. However, early- and late-POST applications can occur during times of stressful environmental conditions, such as high temperatures, which are known to reduce efficacy of several herbicides. This study investigated the effect of temperature stress on efficacy of lactofen in PPO-inhibitor-resistant (KCTR) and -susceptible (MSS) Palmer amaranth. Palmer amaranth plants were grown in two similar growth chambers maintained at 14/10 hours day/night photoperiod, but one chamber was at optimum (OT; 30/20 C d/n) temperature while other was at high (HT; 40/30 C d/n) temperature. Water was supplied daily and was not a limiting factor for plant growth. When plants were at 8- to 10- cm tall, they were treated with lactofen, with doses ranging from 0 to 438 for MSS and from 0 to 1752 g ai ha^{-1} for KCTR. Sixteen replicates were included per treatment, each experimental unity was composed by one plant per pot, and the experiment was repeated. In the second experimental run, the growth chambers were set with the opposite temperature than what they had before, aiming to avoid a possible error due to the environment. Dead or alive ratings were assessed 2 weeks after treatment and analyzed using log-logistic model to determine the dose required to result in 50% of population mortality (LD_{50}). MSS did not show strong LD_{50} variations under contrasting temperatures across experimental runs. Interestingly, LD_{50} increased significantly in KCTR Palmer amaranth under HT compared to OT regime. Results suggest that the efficacy of lactofen is likely to be not altered by HT on susceptible populations, however, HT can significantly result in reduced herbicidal activity under environmental stress in resistant populations. Future work will include the investigation of physiological basis that lead to reduced activity of lactofen in KCTR under high temperature.

Predominance of Metabolic Resistance in a Six-way-resistant Palmer Amaranth (*Amaranthus palmeri*) Population. Chandrima Shyam*, Ednaldo A. Borgato, Dallas E. Peterson, Anita Dille, Mithila Jugulam; Kansas State University, Manhattan, KS (136)

Multiple herbicide resistance (MHR) in Palmer amaranth (*Amaranthus palmeri* S. Watson.) populations across the USA is a serious challenge for its management. Palmer amaranth populations with prevalence of metabolic resistance (non-target site resistance; NTSR) to ALS-, PS II-, and HPPD-inhibitors have been reported in KS. Recently, a Palmer amaranth population (KCTR; KS Conservation Tillage Resistant) from a long-term conservation tillage research project near Manhattan, KS was found uncontrolled by several commonly used herbicides. Importantly, KCTR Palmer amaranth population in this field was not exposed to selection pressure of some of the herbicides to which it showed lack of control. Hence, this study hypothesized that KCTR Palmer amaranth has evolved metabolism-based resistance to several of these herbicides. Therefore, the objectives of this study were to i) confirm the evolution of MHR and ii) determine presence of previously reported target-site resistance (TSR) or NTSR mechanism(s) in KCTR Palmer amaranth. Progenies of KCTR Palmer amaranth that survived 2,4-D (0.56 Kg ha^{-1}) along with susceptible populations i.e., either KSS (KS susceptible) or MSS (Mississippi susceptible) were used in these studies. Fifty plants from KCTR and KSS or MSS (10-12 cm tall) were treated with a field recommended rate of common POST herbicides. Leaf tissue collected from survivors of chlorsulfuron, imazethapyr, atrazine, and glyphosate treated KCTR plants were used to investigate the presence of alterations in *ALS* and *psbA* genes, as well as amplification of *EPSPS* gene. Whole plant bioassays were also conducted with cytochrome P450 (P450) and glutathione-*S*-transferase (GST)-inhibitors to test the efficacy of imazethapyr, atrazine, 2,4-D, lactofen, and mesotrione. In response to POST application, 29 to 100% of KCTR Palmer amaranth survived field recommended rates of 2,4-D, ALS-, PS II-, EPSPS-, PPO-, HPPD-inhibitors, or tank- or pre-mixtures of PS II- and HPPD-inhibitors, confirming evolution of six-way resistance in this population. However, this population was found susceptible to the PS I- and glutamine synthetase-inhibitors. Chlorsulfuron-, imazethapyr- and atrazine-resistant plants lacked previously reported mutations in *ALS* and *psbA* genes, indicating the presence of NTSR mechanisms. KCTR plants surviving glyphosate application showed amplification of the *EPSPS* gene, with up to 88 copies. Pretreatment of P450- or GST-inhibitors along with atrazine, 2,4-D, lactofen, or mesotrione resulted in significantly less biomass accumulation in KCTR plants than those treated with herbicides alone. KCTR plants treated with P450-inhibitor followed by imazethapyr resulted in similar biomass accumulation as MSS plants treated with imazethapyr alone. These findings indicate the prevalence of metabolism-based NTSR, possibly mediated by P450 and GST enzyme activity that has enabled KCTR Palmer amaranth population to evolve resistance to multiple herbicides. This is the first report of evolution of six-way resistance in a single Palmer amaranth population. Metabolism-based resistance can predispose weed populations to evolve resistance to herbicides even with a lack of selection pressure. Future research with this population involves identifying gene(s) which confer metabolic resistance to these herbicides.

The Biologically Effective Dose of Bromoxynil, Applied Alone and Tankmixed with Metribuzin, for the Control of Glyphosate-Resistant Canada Fleabane [*Conyza Canadensis* (L.) Cronq.] Applied Preplant in Soybean. David Westerveld*, Peter Sikkema, Darren E. Robinson, David C. Hooker; University of Guelph, Ridgetown, ON, Canada (137)

Soybean yield loss due to weed interference in North America is estimated to be an average of 52% if no weed management tactics were utilized. Glyphosate-resistant (GR) Canada fleabane (*Conyza canadensis* (L.) Cronq.), first confirmed in Ontario in 2010, can reduce soybean yield up to 67%. Bromoxynil is a photosystem II inhibiting herbicide that is used for post-emergent control of annual broadleaf weeds primarily in monocot crops. The objective of this research is to determine the biologically-effective-dose (BED) of bromoxynil applied alone and when tankmixed with metribuzin (400 g ai ha^{-1}) applied preplant (PP) for control of GR Canada fleabane in soybean in Ontario. Five field experiments were conducted over a two-year period (2019-2020) to determine the dose of bromoxynil +/- metribuzin that provided 50, 80 and 95% GR Canada fleabane control. At 8 weeks after application (WAA) bromoxynil at 98 and 277 g ai ha^{-1} controlled GR Canada fleabane 50 and 80%, respectively. When tankmixed with metribuzin, bromoxynil at 10, 25, and 54 g ai ha^{-1} controlled GR Canada fleabane 50, 80, and 95%, respectively. No soybean injury was observed. At 8 WAA, bromoxynil + metribuzin (280 + 400 g ai ha^{-1}) controlled GR Canada fleabane 97% similar to the industry standards of saflufenacil + metribuzin and glyphosate/dicamba + saflufenacil at 99 and 100% control, respectively. This is the first study that evaluated the utilization of bromoxynil for GR Canada fleabane control prior to seeding soybean; results show that bromoxynil + metribuzin applied PP provides excellent GR Canada fleabane control.

Assessment of Dicamba Movement in Missouri Using a Large-scale Field Trial. Jerri Lynn Henry*[1], Ryan Rector[2], Reid J. Smeda[1]; [1]University of Missouri, Columbia, MO, [2]Bayer Crop Science, St Louis, MO (138)

Large-scale field trials are a realistic method to determine potential sources of off-target dicamba movement. On June 15, 2020 near Centralia, MO a 3.3 ha area of dicamba-tolerant (DT) soybeans was planted inside a larger block of dicamba-sensitive (DS) soybeans; Both areas of soybean were planted the same day and in 38 cm rows. On July 17 prior to R1, dicamba + glyphosate (MON 301286) + Vaporgrip Xtra (MON 51817) + Impetro II (0.5% v:v) was applied to DT soybeans using a commercial sprayer (10.7 m boom) with appropriate nozzle tips. Prior to application, a 3 by 15 m area of DS soybeans adjacent to DT soybeans and in each ordinate direction were covered with plastic to prevent particle drift. At 21 days after treatment (DAT), DS soybeans downwind from the initial application (wind NNE from 4.8 to 9.7 km hr^{-1}) exhibited up to 35% visual injury directly adjacent to DT soybeans, and 5% injury at far as 60 m from the DT soybeans. Upwind, 5% injury to DS soybeans was not observed as little as 2 m from DT soybeans. For soybeans covered by the plastic tarps, visual injury ranged from 10 to 18%. Multi-spectral drone and aircraft imagery (green, red, red-edge, and near-infrared; 550 nm, 670 nm, 717 nm, and 800 nm, respectively) were collected prior to dicamba application through soybean senescence during the 2020 study. Aerial imagery acquired approximately 60 DAT (using enhanced green and red-edge bands) mapped symptomology in DS soybeans displaying initial dicamba injury, with dicamba persisting pass 60 DAT. At soybean harvest in November, DS soybean yields adjacent to DT soybeans were not reduced by factors attributable to dicamba. Although some off-target movement of dicamba downwind was likely the result of secondary movement, the majority of dicamba injury to DS soybeans reflected particle movement at the time of dicamba application.

Interactions of Dicamba, Glyphosate, and Glufosinate Tank-Mixtures for Control of Glyphosate-Resistant Weeds. Adam L. Constine*, Christy Sprague; Michigan State University, East Lansing, MI (139)

Herbicide-resistant common waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer) and horseweed (*Erigeron canadensis* L.) continue to present challenges for soybean growers. The increasing occurrence of herbicide resistance in these two species, paired with their rapid growth habits, extended emergence, and prolific seed production cause them to become two of the most troublesome weed species in production agriculture. New crop technology platforms, such as Bayer's XtendFlex® trait system, provide growers the flexibility to use multiple effective herbicide sites of action for control of herbicide-resistant weeds. XtendFlex® soybean confers resistance to three herbicide sites of action, including: glyphosate, glufosinate, and dicamba. The objective of this research was to evaluate if tank-mixtures that could potentially be used in XtendFlex® soybean were antagonistic, synergistic, or additive for control of glyphosate-resistant common waterhemp and horseweed. Field trials were conducted in 2019 and 2020 to examine glyphosate-resistant waterhemp and horseweed control in Shepherd and East Lansing, MI, respectively. Greenhouse experiments were conducted to further evaluate these tank-mix combinations. In the field, glyphosate-resistant waterhemp in the absence of a crop was sprayed when plants were 10-15 cm in height and approximately at the 5-7 leaf stage. Similarly, glyphosate-resistant horseweed was sprayed when plants were 10-15 cm in height. Glyphosate (1.3 kg ae ha^{-1}), glufosinate (0.65 kg ai ha^{-1}), and dicamba (0.56 kg ae ha^{-1}) were applied alone, in pairs with one another, and in a three-way tank mix. Each treatment was replicated four times. Aboveground biomass was harvested from two $0.25m^2$ quadrats per plot at 14 DAT and data were subjected to Colby's analysis. In the greenhouse, glyphosate-resistant waterhemp and horseweed were subjected to dose response experiments to determine glyphosate, glufosinate, and dicamba rates that provided 25 and 50% (ED_{25} and ED_{50}) biomass reduction. Applications occurred when waterhemp were 15 cm in height and when horseweed rosettes were 10 cm in diameter. Herbicide interaction experiments were then performed utilizing tank-mix combinations of ED_{25}, ED_{50}, and 1X field rates. Aboveground biomass was harvested at 14 DAT and subjected to Colby's analysis. Combinations of glufosinate with glyphosate or dicamba showed antagonistic responses when compared with what was expected. However, not all these antagonisms resulted in poor control. Antagonisms with glyphosate and glufosinate were exaggerated with lower application rates. Although antagonisms were observed for glyphosate + glufosinate and glufosinate + dicamba in the field, overall biomass reduction was greater than 87% for waterhemp and 77% for horseweed 42 DAT. Applications of glyphosate + dicamba provided lower control 14 DAT in the field but by 42 DAT became one of top performing treatments. When all three herbicides were applied together, antagonisms were observed on horseweed and waterhemp control in both the greenhouse and in the field. The results of these studies suggest that growers may see a reduction in control of waterhemp or horseweed with applications of glufosinate mixed with glyphosate or dicamba. However, under most circumstances, acceptable control of glyphosate-resistant waterhemp and horseweed should still be achieved with these tank-mixtures.

Pollen-Mediated Gene Flow from Glyphosate- and Dicamba-Resistant to Conventional Soybean (*Glycine max*). Zahoor A. Ganie*[1], Parminder S. Chahal[2], Amit J. Jhala[3]; [1]FMC Corporation, Newark, DE, [2]FMC Corporation, Lincoln, NE, [3]University of Nebraska-Lincoln, Lincoln, NE (140)

Second-generation genetically modified (GM) multiple herbicide-resistant (glyphosate/dicamba, glyphosate/2,4-D/glufosinate, glyphosate/dicamba/glufosinate, glyphosate/glufosinate /isoxaflutole) soybean traits are important for the control of glyphosate-resistant weeds. However, concerns over the coexistence of GM herbicide-resistant- and conventional or organic soybean cropping systems are critical because of pollen mediated gene flow (PMGF) from the GM soybean to non-GM cultivars that may result in transgenic contamination above admissible limits approved under international trade agreements or regulatory standards. Laboratory analysis of transgenic material in processed soybean products such as soybean oil or animal feed is complicated, uneconomical, and less reliable. The objective of this study was to evaluate PMGF from GM glyphosate/dicamba-resistant soybean to conventional non-GM soybean under field conditions. Field experiments were conducted in 2017 and 2018 using a modified donor-receptor concentric block design. A 400 m^2 pollen-donor block in the center of a field was planted with glyphosate/dicamba-resistant soybean (cultivar 'AG32X8', 3.2 maturity group) and surrounded by receptor block planted with conventional non-GM soybean (cultivar 'ASGROW A3253', 3.2 maturity group) in rows spaced 76 cm apart. At the end of the growing season, seeds of conventional soybean was harvested from various distances (0.5 to 40 m) in eight directions including north (N), south (S), east (E), west (W), northwest (NW), northeast (NE), southeast (SE) and southwest (SW) for screening with dicamba (560 g ai/ha) using dicamba-resistance as a phenotypic marker. Double exponential decay model, selected out of ten competing models based on Akaike's information criteria (AIC) and loglikelihood provided a better fit to explain the PMGF over the distance from the pollen-source during both the years. The highest gene flow was 0.7% and 0.6% in 2017 and 2018, respectively, detected at distance < 2.0 m from the perimeter of pollen-donor block. The model showed that the direction of the pollen-receptor parents with respect to the pollen-donor block did not influence the frequency of PMGF, and the distances estimated for 50% and 99% reduction in PMGF was 0.4 m and 0.5 m in 2017 and 0.7 m and 0.8 m in 2018, respectively.

Optimizing Horseweed Management with Fall-Seeded Cover Crops and Soybean Row Widths. Justine L. Fisher*, Christy Sprague; Michigan State University, East Lansing, MI (141)

Herbicide-resistant horseweed (*Erigeron canadensis* L.) is a problem for Michigan soybean growers, particularly in reduced-tillage systems. Previous research has shown that fall-planted cereal cover crops can suppress early-season horseweed; however, the suppression effects of cover crops on horseweed often do not last until harvest. The combination of fall-planted cereal cover crops and planting soybean in narrow row widths may increase horseweed suppression throughout the entire growing season. A field experiment was conducted in 2020 to investigate the effects of a fall-planted cereal rye cover crop and soybean row width for 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 planted in October 2019 at 67 kg ha^{-1} 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 weeks after planting to half of the treatments, while the other half received a non-effective POST application of glyphosate. Delaying cereal rye termination by 'Planting Green' increased cereal rye biomass to 5349 kg ha^{-1}, compared with 2064 kg ha^{-1} for cereal rye terminated one week prior to planting. Early in the season, prior to peak horseweed emergence, cereal rye did not consistently reduce horseweed biomass compared with the no cover control; however, horseweed density was reduced by 'Planting Green'. At the time of POST herbicide application (4 WAP), horseweed biomass was reduced by 59 and 94% when terminated early and by 'Planting Green', respectively. After POST herbicide applications, treatments with an effective POST provided 100% horseweed control until harvest. For treatments with a non-effective POST, 'Planting Green' reduced horseweed biomass and density by 50 and 54%, respectively. Furthermore, narrow row widths reduced horseweed biomass by 37 and 72% and horseweed density by 33 and 62% with 38 and 19 cm rows, respectively. Soybean yield was reduced by 6% by 'Planting Green', regardless of POST application. This was likely due to a delay in soybean emergence and growth until R1 with 'Planting Green' compared with the no cover and early termination treatments. Additionally, soybean yield was higher in narrower rows compared with 76 cm rows, regardless of POST application. In conclusion, fall-seeded cover crops and narrow row widths provided horseweed suppression compared with no cover and 76 cm rows; however, the effects of early termination did not last through harvest. Delaying cover crop termination with 'Planting Green' produced higher cover biomass and reduced horseweed biomass and density until soybean harvest; however, a yield reduction occurred. The addition of an effective POST herbicide application resulted in 100% horseweed control; though, there was not an increase in soybean yield. Utilizing 'Planting Green' and narrow row widths could improve horseweed suppression through the season and reduce the reliance on herbicides.

Antagonism of ACCase Inhibitor Herbicides Used in Xtend Soybean Systems for Control of Volunteer Corn. Marcelo Zimmer*[1], Bryan G. Young[2], William G. Johnson[1]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, Brookston, IN (142)

Volunteer corn 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 poor setup/operation of combines. Herbicide options for control of volunteer corn in soybean fields depends on the herbicide-tolerance traits of the corn hybrid planted during the previous growing season. Many farmers utilize corn hybrids with stacked resistance to both glyphosate and glufosinate, limiting herbicide choices for postemergence volunteer corn control to the application of ACCase inhibitor herbicides such as clethodim and quizalofop. Synthetic auxin herbicides such as 2,4-D and dicamba are known to antagonize the efficacy of ACCase inhibitor herbicides when used in tank-mixtures. The widespread adoption of dicamba-tolerant soybeans across many regions of the United States has resulted in increased reports of failed ACCase herbicide applications to control grasses. Additionally, acetochlor has been reported to increase the antagonism of ACCase-inhibiting herbicides with dicamba. Field experiments were conducted to evaluate the effect of dicamba (560 g ae ha^{-1}) and acetochlor (1260 g ai ha^{-1}) on the efficacy of different rates of clethodim (70 and 105 g ai ha^{-1}) and quizalofop (31 and 46.3 g ai ha^{-1}) for control of volunteer corn in dicamba-tolerant soybeans. Three F1 corn hybrids with different herbicide-tolerance traits (Non-GMO, SmartStax, and Enlist) were planted across the plots to simulate volunteer corn infestation. The addition of dicamba to clethodim reduced corn control by 14% at the low rate, which is the rate of clethodim traditionally used when the activity of clethodim is not compromised. Dicamba plus acetochlor reduced RR2/LL corn control by 74 and 22% at the low and high rate of clethodim, respectively. In addition, dicamba reduced RR2/LL corn control with quizalofop by 92 and 24% at the low and high rate of quizalofop, respectively. Acetochlor did not appear to affect RR2/LL corn control with quizalofop. Increasing the ACCase herbicide rates by 50% resulted in increased RR2/LL corn control and reduced corn density at soybean harvest. All treatments containing dicamba resulted in standing RR2/LL corn plants at soybeans harvest, except for the high rate of clethodim plus dicamba. All treatments without dicamba resulted in 100% control at soybean harvest. ACCase herbicide rates higher than the rates tested in this experiment may be necessary for control of volunteer corn in dicamba-tolerant soybean systems where dicamba is applied. Split herbicide applications and improved adjuvant use could be other alternatives for overcoming antagonism.

Influence of Agronomic Practices on Soybean Canopy Development and PRE-emergence Herbicide Fate. Nikola Arsenijevic*[1], Ryan P. DeWerff[2], Shawn P. Conley[2], Matthew Ruark[2], Rodrigo Werle[2]; [1]Universtiy of Wisconsin-Madison, Madison, WI, [2]University of Wisconsin-Madison, Madison, WI (143)

With the alarming increase of documented herbicide resistance, weed management is becoming very challenging in soybean cropping systems across the North Central United States and beyond. Growers rely on herbicides for weed control and the role of weed suppression by the cultivated crop is often overlooked. Agronomic practices such as planting time, row spacing, tillage, and use of residual soil-applied herbicides can influence the time of soybean crop canopy closure. The objective of this research was to evaluate the influence of the aforementioned factors on soybean canopy closure and herbicide persistence in soil (pyroxasulfone). A field experiment was conducted at Arlington, WI in 2019 and 2020. The study was a 2x2x2x2 factorial, including early (late April) and standard (late May) planting, narrow- and wide-row spacing (0.38 and 0.76 m, respectively), conventional tillage versus no-till, and the presence or absence of a soil-applied herbicide (Fierce MTZ; flumioxazin + metribuzin + pyroxasulfone, 1.16 L ha $^{-1}$). The study was conducted in a RCBD (16 treatments; 4 replications). Canopy coverage was estimated by taking photos at 2.4 m above soil level at 7-day increments from planting until when ~95% of canopy coverage was attained. Photos were processed in MatLab, via Canopeo add-on package. Estimated time to 90% of canopy coverage (ED_{90}) and soybean yield were subjected to ANOVA using R software where planting time, row spacing, tillage practice, soil residual herbicide, and year were treated as fixed effects and replications nested within years were treated as random effects. According to the ED_{90} results, planting time X soil-applied herbicide X year, planting time X soil-applied herbicide X tillage, planting time X year, and row spacing X year interactions were significant ($P<0.05$). For soybean yield, planting time X year interaction and the main effect of tillage were significant ($P<0.05$). Treatments planted in late April had higher yield than late May planting, and conventional tillage contributed to higher yield compared to no-till system. Soybean yield in 2019 was higher than in 2020. For pyroxasulfone fate in the soil (evaluated from 0-10cm soil depth in mid-June), year, planting time and tillage main effects were significant ($P<0.05$). The highest concentration of pyroxasulfone was observed when soybeans were planted and sprayed in late May under conventional tillage system. In summary, planting soybeans early and adopting narrow row spacing can enhance the rate of canopy closure. Soil-applied herbicides did have a detrimental impact on soybean canopy development but no impact on grain yield. Agronomic practices influenced the soybean canopy development and persistence of soil-applied herbicides indicating they should be better utilized as integrated weed management strategies.

Glyphosate Alternatives for Cereal Rye Termination with Different Application Timings in Soybean. Jose H. de Sanctis*, Amit J. Jhala; University of Nebraska-Lincoln, Lincoln, NE (144)

Cover crops can provide many benefits for the agricultural systems including erosion control, increased nutrient efficiency, greater soil health, reduce soil compaction, and also provide weed control. However, the misuse of this technology can greatly reduce cash crop yields. In Nebraska, the most commonly used cover crop is cereal rye (*Secale cereale* L.). Its increased popularity in soybean cropping systems requires better understanding of termination timings and effective herbicide terminations programs. Glyphosate application is currently the most common termination method, but alternative herbicides programs for terminating cereal rye are not well documented. Therefore, a field study was conducted in 2019 in the South-Central Agricultural Laboratory in Clay County, Nebraska to determine alternative termination herbicide programs in cereal rye at different termination timings. Treatments consisted of clethodim (135.8 g ai ha^{-1}), fluazifop-*P* (140 g ai ha^{-1}), quizalofop (61.6 g ai ha^{-1}), fluazifop-*P* / fenoxaprop (140 g ai ha^{-1} + 39.2 g ai ha^{-1}), and glyphosate (1260 g ai ha^{-1}) applied at three different timings (15 days before planting, soybean planting date, and 15 days after planting soybean). Visual estimations of control were collected weekly until POST emergence applications. At 15 DAT aboveground biomass was collected for cereal rye plants dried at 65^{o}C until constant weight. In addition, soybean stand and yield was collected to investigate potential negative impacts from the different termination timings. Data was subjected to ANOVA in R utilizing the *Agricolae* package. Most herbicides resulted in similar cereal rye control compared to glyphosate for all the termination timings. Glyphosate resulted in >96% control of cereal rye for all the termination timings. Conversely, clethodim resulted in 77.5, 66, and 28% control of cereal rye at 15 days before planting, planting, and 15 days after planting, respectively. Key words: Cover crop, cereal rye, termination timing, termination herbicides, soybean

Interference of Interseeded Winter Wheat on Soybean Growth and Weed Suppression.
Madison R. Decker*, Ronald F. Krausz, Karla L. Gage; Southern Illinois University, Carbondale, IL (145)

Common waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer) is among the most troublesome weeds for Midwestern soybean (*Glycine max* (L.) Merr.) producers due to the selection of biotypes resistant to multiple herbicide sites of action. As herbicide resistance cases increase, and advances in herbicide discovery decline, the need for innovative weed management practices have increased. Therefore, field studies were conducted in 2019 and 2020 at the Southern Illinois University Agronomy Research Center (ARC) in Carbondale, Illinois and at the Belleville Research Center (BRC) in Belleville, Illinois to determine the effect of inter-seeding winter wheat in soybean on common waterhemp suppression and soybean development. A winter wheat termination date study, and a winter wheat planting date by herbicide program study were conducted. Winter wheat termination date and its impact on soybean development in a weed-free study was evaluated at the BRC site. Winter wheat was planted concurrently with soybean and the inter-seeded winter wheat was terminated at various soybean growth stages from vegetative stage V2 until V6. Winter wheat planting date and herbicide programs for the suppression of common waterhemp were evaluated at the ARC and BRC site. Winter wheat was planted on four different dates: prior to soybean planting in October, April, early-May, or at soybean planting in late-May. October planted winter wheat was terminated in April. Herbicide applications included a preemergence (PRE) followed by (fb) a postemergence (POST) program, a POST-only program, hand-weed/non-terminated, and a non-treated comparison. The herbicide program consisted of fomesafen (333 g ai ha^{-1}) + s-metolachlor (1470 g ai ha^{-1}) or sulfentrazone (280 g ai ha^{-1}) + cloransulam (35 g ai ha^{-1}) and s-metolachlor (1506 g ai ha^{-1}) PRE, study dependent, fb dicamba (560 g ai ha^{-1}) + glyphosate (1270 g ai ha^{-1}). Results from the 2019 termination date study indicated no significant differences in yield among inter-seeded treatments terminated by V2 or V3 when compared to the standard soybean-only PRE fb POST program. In 2020, no significant yield differences were detected in any treatment where the winter wheat was terminated when compared to the standard soybean-only PRE fb POST program. In the planting date study, at both locations, 56 days after the POST, common waterhemp suppression was similar in all inter-seeded treatments with an herbicide compared to the standard soybean-only PRE fb POST program (98-99%). Yield from the ARC planting date study indicated that planting winter wheat in the fall or concurrent with soybean resulted in no yield reduction compared to the standard soybean-only plots. In the BRC planting date study, inter-seeding winter wheat at any of the planting dates with a PRE fb POST program yielded the same as the standard soybean-only PRE fb POST program. These data suggest that inter-seeding winter wheat in soybean in combination with an herbicide program could provide additional non-chemical integrated weed management for the suppression of common waterhemp. These studies will be repeated in the 2021 growing season to verify results.

Oat Companion Crop Effects on *Amaranthus spp.* Suppression and Iron Deficiency Chlorosis in Soybean. Jeffery K. Stith*; North Dakota State University, Fargo, ND (146)

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 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 and IDC symptoms were evaluated using a soil plant analysis development logger used to measure chlorophyll content. 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. IDC symptoms were very minor in these experiments, but there were slightly higher chlorophyll content, representing reduced IDC symptoms, at one location when the oat companion crop was planted with soybean. The oat crop did not influence weed biomass until the latest termination timing at either location. Following herbicide application, glyphosate-resistant waterhemp was controlled 39% more at 15 cm when compared to the 60 cm timing, while there were no differences in control of glyphosate-susceptible Powell amaranth (*Amaranthus powelii*) at any termination timing. The highest yield 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. 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. 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 multiple herbicide applications in a more integrated approach.

Efficacy of PRE Herbicides with Single and Multiple Active Ingredients on Residual Waterhemp Control in Wisconsin. Alexandre T. Rosa*[1], Nicholas J. Arneson[2], Daniel H. Smith[2], Ryan P. DeWerff[2], Maxwel Coura Oliveira[2], Rodrigo Werle[2]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Wisconsin-Madison, Madison, WI (147)

Waterhemp (*Amaranthus tuberculatus* (Moq.) J. D. Sauer) is a troublesome weed species in soybean. Multiple sites of action resistance, quick growth, and limited postemergence (POST) control options have resulted in increased reliance on preemergence (PRE) herbicides for waterhemp control. The objective of this study was to investigate the efficacy of commonly applied PRE soybean herbicides for waterhemp control. Soybean trials were established near Lancaster and Brooklyn, WI in the spring of 2018 and 2019 in a RCBD with four replications. Soybeans were established late-May. 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 (1, 2 and 3 SOAs). Herbicide rates were based on soil characteristics and 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 XR11002 flat-fan nozzles. No POST herbicides were applied to the study. Visual herbicide efficacy was collected at 25 and 50 days after treatment (DAT). An analysis of variance was performed with waterhemp control (%), where herbicide treatments, location and year were treated as fixed effects whereas replication was treated as random effect. Wateremp control data was transformed to the beta distribution. All single SOA and multiple SOA combination herbicides except acetochlor, chlorimuron, cloransulam, imazethapyr, metribuzin + chlorimuron, provided above 90% control of waterhemp at 25 DAT. At 50 DAT, the following single SOA and multiple SOA combination herbicides provided above 90% control: dimethenamid, flumioxazin, *S*-metolachlor, pyroxasulfone, flumioxazin + cloransulam, flumioxazin + pyroxasulfone, metribuzin + fomesafen, *S*-metolachlor + metribuzin, sulfentrazone + cloransulam, sulfentrazone + imazethapyr, sulfentrazone + metribuzin, chlorimuron + flumioxazin + pyroxasulfone, flumioxazin + chlorimuron, thifensulfuron, flumioxazin + pyroxasulfone + metribuzin, and saflufenacil + imazethapyr + pyroxasulfone. In 2018 and 2019 several soybean herbicides applied PRE provided effective control of waterhemp past recommended POST herbicide treatment timings. Highest control efficacy, reflected in visual rating, was achieved with combination of group 2, 14, and/or 15 herbicides sprayed at appropriate rates. Future implications include analysis of synergism or antagonism of the active ingredients in combination. This trial showcases the value and efficacy of several PRE soybean herbicides for waterhemp control.

Influence of Environment and Soybean Trait Adoption on Dicamba and 2,4-D Concentrations in Rainwater and Air Deposits Collected Throughout Missouri. Eric G. Oseland*, Mandy Bish, Kevin W. Bradley; University of Missouri, Columbia, MO (148)

The increase in dicamba-resistant (DR) crop technology, and a commensurate increase in dicamba usage, has resulted in thousands of dicamba-related injury claims to non-target crops. The objectives of this research were to: 1) determine seasonal levels of dicamba in rainfall and air deposition samples from 12 regions of Missouri; 2) determine the potential for detected concentrations to cause soybean injury; and 3) evaluate relationships between dicamba concentrations, trait adoption, and weekly weather conditions. In this study, bulk atmospheric samples of wet (rainfall) and dry (sedimented particles) deposition were collected at 12 sites located in different regions of Missouri. Sampling began in late-April and continued weekly through early-September in 2019. Dicamba was extracted from 200 mL water samples using anion exchange solid-phase extraction and concentrations were determined using reverse-phase (C_{18}) HPLC-Photodiode Array with a detection limit 0.025 µg/L. A corresponding survey of soybean producers was performed to determine the percent adoption of DR soybean near each sampling location. A stepwise regression was used to identify relationships of dicamba concentrations with DR trait adoption, temperature inversion frequency, wind speed, air temperature, and humidity. Lastly, dicamba-sensitive soybean were grown and exposed to repeated, simulated rainfall events containing logarithmic dicamba titrations. Results revealed that dicamba was detected in atmospheric samples at least once during the growing season at all sites except the control location that had no DR crops in the region. The highest concentrations of dicamba were detected at three sites located in the southeastern portion of the state where adoption of DR soybean was highest (>85%). At most sites, highest dicamba concentrations occurred during peak spray application periods (May-July) and decreased over the growing season. The concentrations of dicamba detected in atmospheric samples correlated to the adoption of DR crops in Missouri (R^2=.87). Stepwise regression analysis indicated that higher dicamba concentrations were detected in areas where wind speeds during the middle of the day were lower, and where there was a greater duration of the week with inverted temperature conditions. Results from the controlled soybean exposure study revealed that the dicamba concentrations detected in deposition samples were sufficient to cause visual injury to soybean. These results indicate that dicamba has the potential to accumulate in the atmosphere and deposit in rainfall and concentrations are largely influenced by DR trait adoption and atmospheric stability.

Economics of Herbicide Programs for Weed Management in Dicamba/glufosinate/glyphosate-resistant Soybean. Adam Striegel*, Amit J. Jhala; University of Nebraska-Lincoln, Lincoln, NE (149)

Irrigated field experiments were conducted in 2019 and 2020 at the South Central Agricultural Laboratory near Clay Center, Nebraska to evaluate herbicide programs in dicamba/glufosinate/glyphosate-resistant soybean for weed control, crop safety, and crop yield, with an economic comparison of gross profit margins, and benefit-cost ratios. Experiments were arranged in a randomized complete block design with four replications. At 35 d after PRE (DAPRE), acetochlor plus dicamba plus metribuzin, acetochlor/fomesafen plus dicamba, dicamba plus flumioxazin, and imazethapyr/pyroxasulfone/saflufenacil performed similarly, providing 99-80% control of velvetleaf (*Abutilon theophrasti* Medik.), Palmer amaranth (*Amaranthus palmeri* S. Watson), common lambsquarters (*Chenopodium album* L.), and a mixture of foxtail (*Setaria* spp.) and other *Poaceae* species. All PRE programs provided = 89% and = 92% biomass reductions to broadleaf and grass weeds at 35 DAPRE, respectively. At 14 d after early POST (DAEPOST),different combinations of acetochlor, dicamba, glufosinate, and glyphosate provided 80 to 99% control of all grass and broadleaf weeds when following PRE herbicide applications, while most EPOST programs not following a PRE herbicide provided reduced control of grass and broadleaf weeds in comparison. At 28 d after Late-POST (DALPOST), all herbicide programs provided 99 to 83% control of velvetleaf, Palmer amaranth, and grass weed species excluding glyphosate fb glyphosate which provided 27% control of Palmer amaranth. Herbicide programs containing PRE herbicides provided 88 to 99% control of common lambsquarters at 28 DALPOST, while most EPOST and EPOST fb LPOST programs provided 78 to 82% control, respectively. Most herbicide programs evaluated in this study provided = 85% and = 91% biomass reductions for grass and broadleaf weeds at 28 DALPOST. In both site-years, soybean yield was similar for most herbicide programs. Most herbicide programs evaluated in 2020 provided gross profit margins = \$1,000 ha^{-1}, with glufosinate fb glufosinate and imazethapyr/pyroxasulfone/saflufenacil fb acetochlor plus glufosinate provided the highest gross profit margins (\$1,481 and \$1,466 ha^{-1}, respectively). Across herbicide programs, benefit-cost ratios ranged between 0.3 and 3.9 in 2019 due to a significant hail event at the R5-R6 growth stage, whereas in 2020 benefit-cost ratios ranged from 2.9 to 10.9. Results of this study support the use of multiple pass herbicide programs in dicamba/glufosinate/glyphosate-resistant soybean and indicate glufosinate applied POST provided effective control of glyphosate-resistant Palmer amaranth.

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

Evaluation of the Seed Terminator™ as a Harvest Weed Seed Control Tool in Missouri Soybean Production Systems Travis Winans, Brian Dintelmann, Mandy Bish, and Kevin W. Bradley The increasing problem of herbicide resistance in 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 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 that destroy weed seed that pass through the combine, and one of the most common impact mill implements commercially available in Australia is called the Seed Terminator™. In 2019 we investigated the efficacy of the Seed Terminator™ installed on a Case IH 8250 combine on waterhemp infestation in four soybean fields located in central Missouri. Results from the four locations harvested in 2019 indicate that engine load of the combine was from 8 to 31% greater and fuel consumption was 0.2 to 0.5 gallons/acre greater when the Seed Terminator™ was engaged compared to when it was not. Results from this research also revealed that approximately 33% of viable waterhemp seed is lost due to shatter whenever the combine head comes into contact with the waterhemp plant. Of the remaining seed that passes through the combine, approximately 72% of it is directed into the Seed Terminator™, and 92% of that seed will be rendered non-viable. Only 1 of the 4 locations exhibited a significant reduction in the waterhemp seed bank by the spring of 2020, but it is expected that several consecutive seasons of use of the Seed Terminator™ will reduce the seed bank of fields with dense waterhemp infestations.

Saltcedar Control Using Herbicides on the Cimarron National Grasslands. Walter H. Fick*; Kansas State University, Manhattan, KS (151)

Saltcedar (*Tamarix ramosissima* Ledeb.) is a deciduous shrub or tree with a height of about 1 to 7 m. Saltcedar is found throughout the Great Plains and grows best on sandy soils along rivers and streams in southwestern Kansas. Saltcedar has been known to replace cottonwood (*Populus* spp.), willow (*Salix* spp.) and other riparian species. Currently, saltcedar is known to infest over 25,000 ha in Kansas. The objective of this study is to compare the efficacy of five herbicides for saltcedar control. The study was conducted on the Cimarron National Grasslands. Four foliar treatments, 2.4 g L^{-1} imazapyr, 1.2 + 2.7 g L^{-1} imazapyr + glyphosate , 2.4 g L^{-1} imazapic, and 0.13 + 3.7 g L^{-1} aminopyralid + triclopyr, were applied in September of 2017-2019 along with a basal bark treatment of 48 g L^{-1} triclopyr in diesel. The herbicide treatments were applied with a backpack sprayer in 467 L ha^{-1} spray volumes. Ten to 18 trees were treated each year and evaluated for mortality 1 year after treatment. Data were analyzed using Chi Square at $p = 0.10$ level. In 2017, all treatments except aminopyralid + triclopyr provided 100% control of saltcedar. Mortality in 2018 was reduced, probably because of warmer air temperatures and wind speeds greater than 4.4 m sec^{-1} during herbicide application. In 2019, imazapyr, imazapyr + glyphosate, and the basal bark application of triclopyr in diesel all provided greater than 80% control of saltcedar. Imazapyr at 2.4 g L^{-1}, imazapyr + glyphosate at 1.2 + 2.7 g L^{-1}, and imazapic at 2.4 g L^{-1} can all provide acceptable control of saltcedar treated in September under good environmental conditions. Basal bark treatment of saltcedar with 48 g L^{-1} triclopyr in diesel also is effective if all stems are treated properly.

Interaction Between Clethodim and Dicamba in Control of Volunteer Corn. Vitor M. Muller Anunciato*[1], Gabrielle Castro Macedo[2], Daniel Araujo Doretto[3], Caio A. Carbonari[3], Jeff A. Golus[1], Greg R. Kruger[1]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]Teejeet, Sao Paulo, Brazil, [3]UNESP, Botucatu, Brazil (152)

Volunteer corn (*Zea mays*) is often a recurrent weed infesting RR soybean fields. The control of volunteer corn is usually based on the application of ACCase inhibitors, where good control is often achieved in post-emergence applications. However, the antagonistic interactions between ACCase inhibitors and growth regulators tank-mixtures are well reported in the literature. This issue is relevant considering the widespread adoption of dicamba-tolerant soybean in the US, where clethodim + dicamba tank-mixture applications are a common practice among farmers. Additional information is necessary on the efficacy of tank-mixtures of clethodim and dicamba on controlling RR volunteer corn. Tank-mixture interactions, different corn growth stages, and the use of surfactants may affect the control of volunteer corn during applications. Therefore, the objective of this study was to investigate volunteer corn control at different growth stages with dicamba + clethodim tank-mixtures in association with different adjuvants. Those fields study was conducted in randomized complete block design in a factorial treatment arrangement with 4 replications and 2 experimental runs. Treatment solutions included clethodim (76.8, 102 and 136 g ai ha^{-1}) and dicamba (560 g ae ha^{-1}) applied alone or in tank-mixture in combination with NIS adjuvant (0.25% v v^{-1}). All treatment solutions included drift retardant agent (0.5% v v^{-1}). Treatments were applied using backpack sprayer with TTI11002 nozzles calibrated to deliver 140 L ha^{-1} at 276 kPa. Volunteer corn plants were sprayed at different heights (30, 60 and 90 cm). Visual estimations of herbicide injury were recorded at 7, 14, 21, and 28 days after treatment (DAT). Plant above ground biomass was harvested at 28 DAT and oven dried at 65?°C to constant weight. Biomass data were converted into percentage of biomass reduction as compared to the untreated control. Biomass and visual estimations of injury data were subjected to ANOVA test and means were separated using Fisher's Protected LSD test with Tukey adjustment at a = 0.05. Colby's Equation was used to determine the type of interaction occurred. All interactions tend to be antagonistic, it has some exceptions are additive as the treatments applied with the mixture and NIS in 90 cm plants in the 2019 repetition, as well some synergic interactions, but those cases don't repeat in the next year, it can occur due to the error between samples, who gives less power to the statistical analysis and can infer some miss understood. The adjuvant R11 tends to decrease the difference between the observed control and estimated control by the Colby equation, those difference tends to increase when are increased the dose of clethodim, also the control tends to decrease when increase the dose. For the mixture of dicamba and clethodim the best control is achieved when utilized the adjuvant R11 and with the lowest dose of clethodim, as well in the minor stage of control, 30 cm.

Effect of 2,4-D + Florpyrauxifen Applications on Weed Control, Clover Tolerance and Forage Biomass in Grass-legume Pastures in Wisconsin. Jose Luiz Carvalho de Souza Dias[1], Garrett N. Imhoff*[2], Scott Flynn[3], Mark J. Renz[2]; [1]Universtiy of Wisconsin-Madison, Madison, WI, [2]University of Wisconsin-Madison, Madison, WI, [3]Corteva Agriscience, Lees Summit, MO (153)

ProClova (florpyrauxifen-benzyl + 2,4-D; GF-3731) is a new product for broadleaf weed control in pastures. Observations suggest applications control common pasture weeds and some clover species can tolerate ProClova with no seasonal yield loss. As limited information under grazing pressure is available to support these observations, we sought to quantify the efficacy and clover safety of ProClova in two rotationally stocked cool season grass-clover mixed swards. Experiments were conducted from May 2019-2020 in two pastures located near Lancaster (LARS) and Prairie Du Sac (PDS) Wisconsin. Main forage grasses present at both locations included tall fescue (*Lolium arundinaceum S.*), orchard grass (*Dactylis glomerate L.*) and smooth brome (*Bromus inermis L.*). Both white clover (*Trifolium repens L.*) and red clover (*Trifolium pretense L.*) were equally present at LARS, while PDS was predominately white clover. Weed species commonly found at LARS were Burdock (*Artium lappa L.)* and Curly Dock (*Rumex crispus L.)* and at PDS bull thistle (*Cirsium vulgare)*, plumeless thistle *(Carduus acanthoides L.)*, buckorn plantain *(Plantago lanceolata L.)*, and broadleaf plantain *(Plantago major L.)*. ProClova was broadcasted at 24 fl oz/A (2.67 lb. A^{-1} of 2,4-D and 0.036 lb. A^{-1} of florpyrauxifen-benzyl) in spring (LARS 6/1, PDS 5/7) and compared to an untreated control. Results are summarized across both sites, due to a lack of significant site by treatment interaction. ProClova controlled broadleaf weeds as cover was 3.6, 4.1 and 5.8-fold lower compared to untreated areas 30, 60 and 90 DAT, respectively. Similarly, ProClova provided five-fold lower total season weed biomass (104 vs 518 kg DM ha 1 for GF-3731 and control, respectively). White clover cover was similar to untreated areas (> 51%) whereas red clover cover was less than 2% at 30, 60 and 90 DAT. While clover biomass was not separated by species it was three-fold greater on untreated pastures at 30 DAT. No differences in clover biomass were detected at 60 and 90 DAT. This resulted in 57% lower total season clover biomass on ProClova treated pastures (729 kg DM ha-1) compared to untreated pastures (1,282 kg DM ha-1). No differences were detected 30, 60 or 90 DAT or in total season perennial grass biomass. Control persisted one year after treatment as broadleaf weed cover and density were 71% lower than untreated areas. Results indicate that ProClova provided effective control of common pasture broadleaf weeds up to 1 year after treatment. While initial clover (red + white) biomass reductions were detected, negative impacts were transient as no differences were observed 60 DAT. As clover injury was high with red clover, future research should focus on minimizing this impact as this is the predominant clover species in midwestern pastures.

Is There a Magic Bullet? Greenhouse Screening of Herbicides on Bohemian Knotweed (*Fallopia* x *bohemica*). Roger Becker*, Alan G. Smith, Neil O. Anderson, Ryan Mentz, Jeanie Katovich, Mary Marek-Spartz; University of Minnesota, St. Paul, MN (154)

Control of knotweeds with herbicides has been inconsistent, costly, requires follow-up treatments, and may have significant environmental impacts. It is difficult to perform comparative studies on invasive knotweed control with herbicides in the field for several reasons. Have we missed finding the “magic bullet” for knotweed control? To find out we conducted exploratory herbicide efficacy and optimization studies in the greenhouse with perennated potted juvenile clones of Bohemian knotweed collected from a single source screening 22 herbicide active ingredients and five modes of action with titrations of several key herbicides. Efficiencies of greenhouse trials allows screening many treatments and rate titrations under the same conditions to better define relative activity on knotweeds within chemistries and modes of action. Inconsistent control has been reported with aminopyralid and aminocyclopyrachlor, but both performed very well in this initial trial. As anticipated, imazapyr provided the highest unit activity and consistency of the imidazolines tested. Flumioxazin was shown to have potential in an U.S. Army Corp screening but we found it did not perform well. Carfentrazone applications at rates that performed well on giant bur-reed (*Sparganium eurycarpum*) in cultivated wild rice were ineffective on Bohemian knotweed. Flazasulfuron activity observed in England was not observed in our first trial and glyphosate, as often seen, left questions as to whether plants will recover. These findings will be updated with a repeat of the trial. Additional work to inform herbicide optimization based on source-sink relationships will be discussed.

Spatial Modeling of Canopy Penetration. Rone Batista de Oliveira*; UENP, Fargo, Brazil (155)

The characterization of a pesticide application method is spatial-dependent process and needs to be studied in multiple directions because it is random, structured and stochastic. The objective of this study was to analyze the spatial variability of spray deposition and droplet coverage on soybean crop with different nozzle types and droplet size classifications. Applications were made through XR11002, J3D11002, AIXR11002, and TTI11002 nozzles at 200 kPa pressure. A carrier volume of 100 L ha-1 was delivered using a self-propelled sprayer at 2.8 m s-1 travel speed. A tracer was added to the solution at 6 g L-1. After applications, artificial collectors positioned at the top and bottom of soybean plants were collected and placed into plastic bags. In laboratory, the tracer deposited on collectors was quantified by spectrophotometry. Data were analyzed using geostatistical tools (Variogram and Cross-validation). Similarity comparisons between deposition and coverage maps were based on agreement index, confidence index and Root Mean Square Error. Spatial variability for spray deposition and droplet coverage was observed for all tested nozzles. All nozzles produced similar spray deposition and droplet coverage on collector positioned at canopy level. The coverage was lower at both top and bottom of the canopy for the TTI nozzle in both locations, probably due to the large droplet size produced by the TTI nozzles in comparison to the other nozzles tested. The coverage and deposition at the top of the canopy may not be a reliable indicator of what to expect in terms of performance of the nozzle at the bottom of the canopy. The analysis of spray quality only by means could hide the variability of spray process and create generalizations that fine droplets are the only option to achieve adequate coverage and deposition. Future research needs to be conducted to associate these results with biological activity.

Engineering Considerations Associated with the Application of Agrochemicals Using Unmanned Aerial Systems (UAS). Bradley K. Fritz*; USDA ARS, College Station, TX (156)

Abstracts were not requested for symposia and were submitted on a voluntary basis.

Automatic Weed Spectrum and Weed Pressure Assessment Using Imagery Data. Marek M. Schikora*; BASF, Langenfeld, Germany (157)

Latest research indicates that weeds are the most dangerous threat to the yield potential of a field. In cereal fields the weed biomass present in a field can explain up to 31% of the variation of yield loss. An informed assessment of the current situation on a field is the first step to develop a successful weed management strategy. The observation points that are essential are: the spectrum of weed species present, their distribution, their number per area, their growth state and the ground area already covered by weeds. A system for a further automated system for hyperlocal weed management is presented here. Which is able to provide in real time a weed spectrum and weed pressure analysis based on imagery. To allow farmers an easy self-assessment of his weed situation the technology is available as part of the xarvio SCOUTING app and will be scaled into further embedded applications. The component Multi-Weed Identification is capable to deliver the following weed stress indicators from a single photo: number of weeds present in the picture, percentage of weeds covering the area observed, number of weeds per square meter, a list of weed plants identified. We use deep learning, augmented reality and an annotated imagery data base from more than 3 million users collected during the last 5 years. The workflow is the following: First, the farmer goes to his field and takes a photo. During the camera activation phase the app is building a 3D model of the underlying scene. From this we can estimate the area covered by the field of view of the camera lens. Secondly, this information is passed together with the picture to a server-based application, where further analysis is done. The content of the picture is passed through a multi-task neural network. This network is trained to detect potential weeds in field situations. For each potential plant detected a multi-task classification is performed. The algorithm at hand is using the taxonomy information available and thus is able to identify the species, genus, family and category of the plant. However, for really small plants, e.g. in the seedling growth state, not enough features are visible to identify the species with a high confidence. In that situation the algorithm tries to identify the Genus. If also this is not possible, it tries to identify the Family. If even this is not feasible, we still identify the category of the plant, e.g. dicot or monocot. Having this information for each plant we are able to deliver the weed spectrum present. We have tested the capabilities of the application on a representable set of pictures provided by users and in field evaluation campaigns. Independent research has proved that our application is well suited to identify weeds, especially in young growth state. With xarvio SCOUTING Multi-Weed Identification we propose the first solution in the world that is able to deliver an essential data layer for a targeted weed management to the farmer - with a single photo of his field.

Untapped Opportunities for Wind Tunnel Testing. Steven A. Fredericks*; WinField United, River Falls, WI (158)

Wind tunnel testing has been historically leveraged in agricultural research to improve understanding of spray applications. This testing has primarily focused on measurement of droplet size distributions as a function of nozzle selection and tank mix constituents. These measurements have historically been correlated with field data or input into models to predict both spray performance and drift potential. Although this approach has been effective there is still large untapped opportunity for wind tunnel testing to advance understanding of spray application and to create actionable insight for the field. In this talk other research opportunities are discussed which can leverage the advantages of wind tunnel testing. These include validation and development of field drift samplers, novel spray visualization techniques, boom scale drift measurements, and exploring wind as a plant stresser.

Electronically Actuated Nozzle Bodies – Enabling Hands Free Nozzle Switching. Nicholas J. Fleitz*[1], Luis Dowling[2]; [1]Pentair Hypro, New Brighton, MN, [2]Pentair Hypro, Lincoln, NE (159)

Pentair Hypro is introducing a new application technology system in 2021, dubbed the “Quad Nozzle Body”. This new precision application system utilizes electronically actuated valves to switch between nozzles, allowing the applicator to switch between different spray nozzles from the cab. This feature allowing applicators to more easily switch between nozzle types corresponding with the specific chemistry being applied or to match the weather conditions at time of application will promote greater application efficacy and stewardship of pesticide chemistries. GPS based individual nozzle control prevents overlap on adjacent sprayer passes, point rows, maintenance of waterways and field borders as well as crop protection chemical savings of up to 5%. The use of ball valve technology allows for greater nozzle technology flexibility than other precision application systems utilizing solenoid valves. The “Quad Nozzle Body” also provides switching between nozzle pairs of incremental size variations during speed and pressure changes that occur while spraying across a field. This maintains more consistent droplet sizing and can reduce off-target drift potential through limits in fine droplet production.

Fifty Years of Pesticide Application Technology. Robert Klein*; UNIVERSITY OF NEBRASKA, North Platte, NE (160)

The dryland cropping system, until the early 1970's, in Southwest Nebraska was Winter Wheat and Fallow, or 1 crop in 2 years. This involved as many as 9 tillage operation in controlling weeds and preparing a seedbed for Winter Wheat seeding. Some tried Corn, grain sorghum or other crops, using tillage for weed management and seedbed preparation, but this was usually not profitable because of the low yields. In Southwest Nebraska, it requires about 2 tons of crop residue to maintain soil organic matter per year or the crop residue from 80 bushels of winter wheat in the winter wheat-fallow cropping system. Winter wheat yields in Southwest Nebraska from 1956 to 1970 averaged 18.3 bushels or 23% of what was needed to maintain soil organic matter. Hence soil quality deteriorated. In the early 70s, we started spraying winter wheat stubble fields shortly after winter wheat harvest. This was in preparation to planting no-till corn or grain sorghum the next spring or even no-till or reduced till winter wheat the next fall. There were many weeds not controlled and application errors have been blamed for 85 to 90% of herbicide failures. A Nebraska study found that only 30% of the cooperators were applying herbicides within 5% of their intended application rate. Herbicide failures were associated with selection of nozzle type, mismatched, plugged or badly worn nozzles, nozzle spacing, nozzle pressure, uneven pressure in lines, nozzle height and nozzle angle. Speed of the sprayer, the sprayer's effect on the spray pattern, wind speed, mixing and calibration errors are among other factors that contributed to herbicide failures. Also, marking system, or lack of, was a problem with some even getting the family out to help mark the field with flags. Equipment was assembled at the University of Nebraska West Central Research and Extension Center located at North Platte to analyze spray patterns under field conditions. Rhodamine dye solution was added to the sprayer tank. A track was used to hold a paper tape, similar to adding machine tape. The sprayer was then run over the tape at the same speed and pressure as in field spraying. The ends of the paper tape were covered so they were not contaminated with the spray solution containing the dye, as a zero referencing point is needed for the fluorometer. The fluorometer was interfaced with a computer and flatbed chart recorder. Clinics were held to analyze the quantity of spray as well as the quality of the spray pattern using the computer analyzation equipment. Recommendations were made to improve the spray quantity and quality of the spray pattern. The last performance improvement included the use of a laser to determine spray particle sizes. This included how nozzle type, pressure, pesticides, and additives affect the spray particle size. In summary with no-till production of corn and/or grain sorghum in the cropping system with winter wheat or 2 crops in three years vs winter wheat-fallow, a crop every other year, the economics of dryland farming in Southwest Nebraska improved. With the increase in yields of winter wheat, corn or grain sorghum we were able to produce enough crop residue to maintain or even increase soil organic matter. We also learned how effective winter wheat crop residue is in suppressing weeds.

Application Technology: Where We Are Going? Greg R. Kruger*; University of Nebraska-Lincoln, North Platte, NE (161)

Abstracts were not requested for symposia and were submitted on a voluntary basis.

Battling Resistant Weeds with Spot Spray Technology WEED-IT. Albert Bosscha[1], Hans IJken*[2]; [1]Rometron, Don't Know, Netherlands, [2]Rometron, Steenderen, Netherlands (162)

Abstracts were not requested for symposia and were submitted on a voluntary basis.

Management of Velvetleaf by Tank-mixing Glufosinate and Fluthiacet-methyl in Glufosinate-resistant Soybean. Parminder S. Chahal*[1], Zahoor A. Ganie[2], Amit J. Jhala[3]; [1]FMC Corporation, Lincoln, NE, [2]FMC Corporation, Newark, DE, [3]University of Nebraska-Lincoln, Lincoln, NE (163)

A field study was conducted at the South Central Agricultural Laboratory near Clay Center, Nebraska in 2018 and 2019 to evaluate the effect of glufosinate and fluthiacet-methyl tank-mixed at different rate combinations for control of velvetleaf and their effect on yield in glufosinate-resistant soybean. In 2018, glufosinate at 594 or 740 g ai ha^{-1} or fluthiacet at 4.8 to 7.2 g ha^{-1} applied alone or as tank-mixed partners provided statistically similar velvetleaf control of 79 to 96% and 81 to 99% at 14 DAT and 28 DAT, respectively. Similarly, in 2019, glufosinate or fluthiacet applied alone or in tank-mixtures provided similar control at 14 DAT. However, glufosinate 594 g ha^{-1} + fluthiacet 7.2 g ha^{-1} and glufosinate 740 g tank-mixed with fluthiacet 6.4 or 7.2 g ha^{-1} provided greater velvetleaf control compared to lower rate of glufosinate applied alone. Fluthiacet alone at all rates provided similar control as fluthiacet + glufosinate tank-mixtures at 28 DAT. In 2019, velvetleaf density was reduced 87 to 100% by higher fluthiacet rates applied alone and by all fluthiacet + glufosinate combinations compared to 37 to 54% density reduction with glufosinate applied alone at 594 or 740 g ai ha^{-1}. Similarly, higher fluthiacet rates applied alone and fluthiacet + glufosinate combinations provided greater (96 to 100%) biomass reduction of velvetleaf compared to glufosinate applied alone at both rates (61 to 74%) in 2019. Glufosinate 594 or 740 g applied alone or tank-mixed with fluthiacet 4.8 to 7.2 g ha^{-1} resulted in greater soybean yield 2,082 to 3,177 kg ha^{-1} compared to nontreated control in 2018. Soybeans were destroyed in 2019 by strong winds followed by rainfall before harvest; therefore, yield data not available. The results suggested that glufosinate and fluthiacet belonging to distinct site of action can be tank-mixed to effectively control velvetleaf in glufosinate-resistant soybean.

Influence of Various Broadleaf Herbicides on the Control of Corn and Other Grasses with Clethodim Herbicides. Gregory K. Dahl*[1], Joshua J. Skelton[2], Ryan J. Edwards[3], Laura J. Hennemann[3], Lee A. Boles[3]; [1]WinField United, Eagan, MN, [2]WinField United, St. Paul, MN, [3]WinField United, River Falls, WI (164)

Studies were conducted in 2020 at River Falls, Wisconsin to document the influence of broadleaf herbicides on the performance of clethodim herbicide for control of corn and other grasses. A video was made in August 2020 featuring one of the studies. The intended audience for the video was agronomists and farmers. The video was incorporated into the presentation being made at the 2020 North Central Weed Science Meeting. Section® Three clethodim was applied at 59 g ai ha^{-1} and 118 g ai ha^{-1} alone, or with a High Surfactant Oil Concentrate, HSOC at 0.6 l ha^{-1}. The clethodim and HSOC were applied alone or with dicamba, 2,4-D choline or bentazon. The dicamba was applied at 1.6 l ha^{-1}. The 2,4-D choline was applied at 2.33 l ha^{-1} and the bentazon was applied at 2.33 l ha^{-1}. The spray volume was 140 l ha^{-1}. The dicamba containing treatments were sprayed with TTI 11002 nozzles. The other treatments were sprayed with AIXR 11002 nozzles. The treatments were applied at 414 kPa. Corn was approximately 36 cm in height when the treatments were applied. Clethodim applied at 59 g ai ha^{-1}and 118 g ai ha^{-1}with HSOC at 1.6 l ha^{-1}provided 95% and 97% corn control, respectively, 23 days after treatment. Clethodim at 59 g ai ha^{-1} and 118 g ai ha^{-1} alone provided only 23% and 50% corn control, respectively, 23 days after treatment. Clethodim applied at 59 g ai ha^{-1} with HSOC at 1.6 l ha^{-1} plus dicamba, 2,4-D choline and bentazon provided 55, 45 and 29% corn control, respectively, 23 days after treatment. Corn control with clethodim at 59 g ai ha^{-1} plus HSOC was much less when tank-mixed with the broadleaf herbicides compared to clethodim plus HSOC alone. Clethodim applied at 118 g ai ha^{-1} with HSOC at 1.6 l ha^{-1} plus dicamba, 2,4-D choline and bentazon provided 93, 97 and 85% corn control 23 days after treatment. Corn control with clethodim at 118 g ai ha^{-1} plus HSOC was equal to or similar to when tank-mixed the broadleaf herbicides compared to the 97% corn control with clethodim plus HSOC alone. When tank-mixing clethodim with dicamba, 2,4-D choline or bentazon, clethodim should be used at rates high enough to overcome potential herbicide antagonism.

A23372A - A Broad-Spectrum Solution for Superior Weed Management in Soybean. Brett R. Miller*[1], Tom H. Beckett[2], Peter Eure[3]; [1]Syngenta Crop Protection, Fargo, ND, [2]Syngenta Crop Protection, Greensboro, NC, [3]Syngenta Crop Protections, Greensboro, NC (165)

A23372A is a new herbicide being developed by Syngenta Crop Protection for broad-spectrum control of annual grasses and key broadleaf weeds in soybeans. The active ingredients contained in A23372A are *S*-metolachlor, metribuzin and cloransulam-methyl in a ratio that delivers robust rates of all three herbicides in a convenient mixture. In field testing, A23372A displays excellent crop safety across soil types and environments in all regions of the country. This new herbicide mixture 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 *A. trifida*), morningglories (*Ipomoea spp.*) and velvetleaf (*Abutilon theophrasti*). A23372A is being developed for broad use 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. A23372A protects 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.

Control of Volunteer Enlist E3® Corn (*Zea mays*) in Enlist E3® Soybean (*Glycine max*). Rui Liu*[1], Isaac N. Effertz[2], Taylor Lambert[1], Vipan Kumar[1]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Manhattan, KS (166)

Volunteer corn interfere with soybean growth and can cause significant yield loss. Recent development of Enlist® corn allow the use of 2,4-D choline, glyphosate, and aryloxyfenoxypropionate (FOP) herbicides for grassy and broadleaf weed control. However, volunteer Enlist® corn in Enlist E3® soybean could be management concern for producers who follow corn-soybean rotation. The main objective of this research was to determine the effectiveness of cyclohexanedione (DIMs) herbicides alone or in combination with 2,4-D choline for control of 2,4-D/glyphosate/glufosinate/FOP-resistant volunteer corn in 2,4-D/glyphosate/glufosinate soybean. Field experiment was conducted in 2020 growing season at Kansas State University Agricultural Research Center (KSU-ARCH) near Hays, KS. An Enlist® corn hybrid "DKC62-53" was planted at seeding rate of 43,027 seeds ha^{-1} on May 13 and an Enlist E3® soybean variety "P30T92E" was planted in perpendicular direction on May 20. Herbicide treatments, including clethodim and sethoxydim were tested alone or in tank-mixtures with 2,4-D choline as early POST (20-30 cm tall corn), or late POST (30-76 cm tall corn). All treatments were arranged in a randomized complete block design with 4 replications. Data on visible control (%) of corn were recorded at 14, 28, 42, 56, and 98 days after treatment (DAT). The aboveground shoot dry biomass of corn, and soybean grain yields (kg ha^{-1}) were determined at soybean maturity. Results indicated that clethodim applied alone EPOST can effectively control (95-99%) volunteer Enlist® corn in Enlist E3® soybean throughout the season. Adding 2,4-D choline to clethodim did not alter its efficacy. Sethoxydim applied EPOST was able to provide similar control as clethodim; however, adding 2,4-D choline significantly reduced its efficacy. All LPOST treatments provided low to moderate level control (50-85%) of Enlist® corn. The biomass reduction (%) of Enlist® corn with EPOST application of clethodim applied alone was the highest (100% reduction). Soybean yield didn't differ among all the EPOST treatments (2640-2953 kg ha^{-1}), while the soybean yield from all the LPOST treatments (2368-2514 kg ha^{-1}) were significantly lower. In conclusion, these results suggest that clethodim and sethoxydim applied EPOST alone can effectively control volunteer Enlist® corn in Enlist E3® soybean. The addition of 2,4-D can compromise the efficacy of the two graminicides. Furthermore, the herbicide treatments should be applied early in the season in order to achieve effective, season-long control of volunteer Enlist® corn.

Influence of Multiple Sites of Action and Residual Herbicide Application Timing on Season-Long Waterhemp (*Amaranthus tuberculatus (Moq.) J. D. Sauer*) Control in Soybean. Travis Legleiter*[1], J D. Green[2]; [1]University of Kentucky, Princeton, KY, [2]University of Kentucky, Lexington, KY (167)

Glyphosate-resistant *Amaranthus tuberculatus* continues to spread across the state of Kentucky and remain a predominate weed problem for many Kentucky soybean producers. In addition to widespread glyphosate resistance, PPO-resistance has now also been confirmed in this species in Kentucky and is suspected to be spreading. University of Kentucky research over the past half-decade has consistently shown the benefits of residual herbicides, and more specifically residual herbicides with multiple sites of action, for control of *A. tuberculatus* in soybean. Despite this research the incentive of soybean producers to invest in multiple site of action residuals is lacking, especially with multiple effective postemergence options now available in stacked herbicide-resistant soybean varieties. Field studies were conducted during the summer of 2020 to evaluate the influence of herbicide residual application timing and number of sites of action on *A. tuberculatus* control. These studies were conducted at two locations on farmer owned fields with infestations of *A. tuberculatus* in Taylor and Caldwell County, Kentucky. The treatment structure evaluated the following residual herbicide approaches: Multiple site of action residual applied preemergence followed by an additional residual site of action postemergence; Multiple site of action residual applied preemergence only; Single site of action residual applied preemergence followed by an additional site of action postemergence; and Single site of action residual applied preemergence only. In addition, non-residual foliar active postemergence herbicides were applied when *A. tuberculatus* plants reached 5 to 10 cm in height based on herbicide-resistance soybean trait at each site. Visual evaluations four weeks after preemergence and postemergence applications, as well as end of season *A. tuberculatus* densities consistently showed that metribuzin plus chlorimuron resulted in lower *A. tuberculatus* control than flumioxazin plus pyroxasulfone plus chlorimuron at Taylor County and all other treatments at Caldwell County. Evaluations of overall program approach revealed that *A. tuberculatus* control was reduced with a single site of action residual applied preemergence as compared to all multiple site of action residual approaches at Caldwell County, which had a significantly higher population density of *A. tuberculatus* than Taylor County. Differences in overall residual program approach were not found at the Taylor County research study. Within this research, the sequence of residual herbicide applications within a multiple site of action residual program did not influence *A. tuberculatus* control. Results from these studies highlight the need for robust multiple site of action residual herbicide programs for control of heavy infestations of *A. tuberculatus*, although this short-term benefit was not realized in a lesser infestation of *A. tuberculatus*. Thus, the message of long-term benefits of herbicide resistance management and use of multiple site of action residuals must continue as we move forward through this era of stacked herbicide resistant soybean.

Influence of Glufosinate Tank-mix Combinations with PPO-inhibitors on Waterhemp Control, Crop Injury and Yield in Enlist E3 Soybeans. Rodrigo Werle*[1], Nicholas J. Arneson[1], Ryan P. DeWerff[1], Daniel H. Smith[1], Nikola Arsenijevic[2], Mark L. Bernards[3]; [1]University of Wisconsin-Madison, Madison, WI, [2]Universtiy of Wisconsin-Madison, Madison, WI, [3]Western Illinois University, Macomb, IL (168)

Glufosinate is expected to play a major role in POST-emergence broadleaf weed control in soybean cropping systems. Application strategies aimed at enhancing consistency of broadleaf weed control and mitigating resistance evolution are warranted for this herbicide. In 2020 we conducted two field studies, each at two Wisconsin and one Illinois location (RCBD, 4 replications). The first study evaluated the impact of glufosinate tank-mixes with PPO-inhibitors (flumiclorac, fluthiacet-methyl, fomesafen, and lactofen at recommended and reduced rates; 1X and 1/3X label rate), bentazon (1X and 1/3X label rate), and 2,4-D choline (1X label rate) on waterhemp control 14 DAT compared to each herbicide sprayed alone. The second study evaluated crop phytotoxicity 14 DAT and yield response to the aforementioned treatments in absence of weed competition (the second study was kept weed-free). All treatments received a PRE-emergence application and POST-emergence treatments were sprayed when the crop reached V3-V6 stage, depending on location. Glufosinate tank-mix combinations enhanced waterhemp control 14 DAT when compared to herbicides applied alone. Lactofen treatments presented the highest crop phytotoxicity 14 DAT. Yield drag was observed for some of the glufosinate + PPO-inhibitor tank-mixes. This study will be replicated in 2021 to validate waterhemp control results and to allow further yield evaluations.

Herbicide Weed Control Program in XtendFlex® Soybean. Neha Rana[1], Cody Evans[2], Devin Hammer*[3], Ryan E. Rapp[4], Rod Stevenson[5], Carl Coburn[1], Blake Barlow[6]; [1]Bayer Crop Science, St Louis, MO, [2]Bayer Crop Science, Franklin, IL, [3]Bayer Crop Science, Mankato, MN, [4]Bayer Crop Science, Mitchell, SD, [5]Bayer Crop Science, Delton, MI, [6]Bayer Crop Science, Columbia, MO (169)

Field studies were conducted in 2020, bareground trial and XtendFlex® soybean, to evaluate grass control with XtendiMax® herbicide with VaporGrip® Technology and Roundup PowerMAX® herbicide with various tank-mix components like MON 51817 (VaporGrip® Xtra Agent), group 15 herbicide, and adjuvants. In 2020, 36 field studies were conducted in ND, MN, WI, MI, DE, NE, IL, IN, VA, IA, MO, KS, OK, MS, AL, GA, TN, and TX. 23 of these trials were with university academics. Field trials targeted large weeds, particularly grasses, to simulate hard-to-control situations. In the bareground trial, 21 days after postemergence application, XtendiMax herbicide (0.5 lb ai A^{-1}) + Roundup PowerMAX herbicide (1.125 lb ai A^{-1}) + VaporGrip Xtra Agent (1% v/v) was not significantly different compared to Roundup PowerMAX herbicide (1.125 lb ai A^{-1}). XtendFlex soybean trial achieved higher level of grass control when Warrant® herbicide was in the tank with XtendiMax herbicide (0.5 lb ai A^{-1}) and Roundup PowerMAX herbicide (1.125 lb ai A^{-1}) 28 days after early postemergence (EPOST) application. Addition of adjuvant in the XtendFlex soybean trial did not have an impact on broadleaf or grass control 28 days after EPOST. 2-Pass herbicide programs in the XtendFlex soybean trial resulted in high levels of grass and broadleaf control compared to one-pass herbicide program regardless of mid-postemergence application.

XtendiMax® with VaporGrip® Technology is a Restricted Use Pesticide.

Weed Efficacy and Crop Safety with MON 51817 in Roundup Ready® Xtend Crop System.
Neha Rana[1], Ryan Rector*[1], Ryan E. Rapp[2], Cody Evans[3], Devin Hammer[4], Carl Coburn[1], Rod Stevenson[5], Blake Barlow[6]; [1]Bayer Crop Science, St Louis, MO, [2]Bayer Crop Science, Mitchell, SD, [3]Bayer Crop Science, Franklin, IL, [4]Bayer Crop Science, Mankato, MN, [5]Bayer Crop Science, Delton, MI, [6]Bayer Crop Science, Columbia, MO (170)

XtendFlex® Soybean field trials were conducted in 2020 to evaluate postemergence (POST) XtendFlex® soybean safety and weed control with XtendiMax® herbicide with VaporGrip® Technology + Roundup PowerMAX® herbicide tank-mixed with and without MON 51817 (VaporGrip® Xtra Agent) and various tank-mix components like drift reduction adjuvants (DRA), and group 15 herbicide. In 2020, 24 field studies were conducted in ND, SD, MN, IA, IL, IN, OH, MO, KS, NE, NC, PA, MS, AR, and LA. 16 of these trials were with university academics. Results from these trials indicated no significant differences were detected in broadleaf and grass control and crop response on XtendFlex soybean when VaporGrip Xtra Agent (1% v/v) was added to the tank with XtendiMax herbicide (0.5 lb ai A^{-1}) and Roundup PowerMAX® herbicide (1.125 lb ai A^{-1}). With different approved DRAs and VaporGrip Xtra Agent in the tank with Warrant® herbicide (1.125 lb ai A^{-1}), XtendiMax herbicide (0.5 lb ai A^{-1}) and Roundup PowerMAX herbicide (1.125 lb ai A^{-1}), no significant differences were detected in broadleaf and grass control and crop safety on XtendFlex soybean. XtendiMax® with VaporGrip® Technology is a Restricted Use Pesticide.

Introduction to Symposium and Call to Action. Nicholas J. Arneson*; University of Wisconsin-Madison, Madison, WI (171)

Extension outreach efforts are vital for adoption of effective weed management strategies. While typically relying on face to face meetings and in-person educational trainings, extension professionals have been forced to adapt due to the unexpected COVID-19 pandemic. This symposium's purpose is to share and learn about innovative methods that extension programs have executed considering recent events. A survey was conducted of Extension weed scientists across the US on how COVID-19 impacted their respective outreach programming. Results from 37 extension weed scientists representing 26 states will be shared. Extension specialists from weed science, agronomy, soil science, and plant pathology will share insights on their innovative outreach efforts over recent years with specific emphasis on what techniques have proven effective through limited direct interaction with farmers and decision influencers. Panel discussion will follow our invited speakers' presentations that will serve as a starting point for on-going discussions on how extension professionals can continue to elevate their outreach programming.

Café Talks: Meeting Farmers in Their Comfort Zone. Abby M. Wick*; North Dakota State University, Fargo, ND (172)

Abstracts were not requested for symposia and were submitted on a voluntary basis.

The Nebraska On-Farm Research Network: Innovative and Impactful Extension Work During COVID and Beyond. Laura Thompson*; University of Nebraska-Lincoln, Lincoln, NE (173)

Abstracts were not requested for symposia and were submitted on a voluntary basis.

Extensions Community-based Efforts to Combat Palmer Amaranth and Steward Pesticide Use in Georgia. A Stanley Culpepper*; University of Georgia, Tifton, GA (174)

As the world's population is expected to approach 10 billion people by 2050, family farms are challenged with the task of providing food, feed, and fiber for all. The University of Georgia (UGA) Cooperative Extension Service is not only prepared to help farmers overcome their challenges, but to help accomplish these tasks in ways that are more efficient and effective while being better stewards of agriculture. Armed with 125 agricultural agents located across the state coupled with 98 departmental faculty having extension appointments, UGA Extension rapidly conducts unbiased applied research and communicates those results directly to family farms and other clientele. Managing Palmer amaranth and stewarding pesticides are two areas of weed science where extension is playing a critical role. Although Palmer amaranth continues to be problematic, a survey noted that 96% of Georgia growers were improving the control of this pest as they 1) made more timely herbicide applications, 2) hand weeded escapes, 3) overlapped residual herbicides, 4) followed a start clean – stay clean approach, and 5) utilized different herbicide modes of action. Growers also noted that the most effective approach to help them further improve management in the future would be to continue in-person county extension meetings; additional helpful approaches also included increased applied research efforts, new technologies, variety trials in their area, and increased UGA Extension farm visits. Pesticide stewardship is a requirement for farm sustainability. In 2014, UGA Extension and the Georgia Department of Agriculture developed an educational training platform titled “Using Pesticides Wisely” (UPW). This program shares innovative research results from over 125 experiments designed to help pesticide applicators improve on-target pesticide applications. From 2015 through 2020, the classroom training was conducted in-person at 78 locations with 7,255 people in attendance; 4 virtual (in response to COVID) trainings with 257 people also occurred. In addition to the classroom training, 42 Extension Agents visited farms further training growers and applicators (>1000 individuals) on methods that they could implement specifically on their farms to improve pesticide stewardship. Since the beginning of the UPW training program, UGA Extension has documented a 77% reduction in pesticide drift complaints. In 2019, growers were asked “what was their most reliable source for information regarding weed control and pesticide stewardship”. Of the 1347 individuals willing to write in a response to the survey, the Cooperative Extension Service was listed the most at 1008 times.

'App'-riculture: Putting Plant Disease Prediction in the Hands of Farmers. Damon Smith*; University Wisconsin, Madison, WI (175)

Farm production has become increasingly reliant on technology to improve accuracy of management decisions and production efficiency. Along with this wave of technology use, major breakthroughs in plant disease modeling and prediction have been made in basic science. These concurrent trends have made it possible to put the latest research-based disease prediction and management technology directly in the hands of farmers. This presentation will highlight on-going work to develop smartphone-based applications (apps) that were built on a basic research foundation and are used to predict and manage plant disease in the field. The discussion will include the apps Sporecaster, Sporebuster, and Tarspotter. Information on how they were developed and validated, how they should be used, and public impressions will be presented.