WSSA Virtual Annual Meeting

February 15 to 19, 2021

Abstracts – Table of Contents

Herbicide-Resistant Palmer Amaranth (*Amaranthus palmeri* S. Wats.) and Common Waterhemp (*Amaranthus tuberculatus*) in Kansas. Vipan Kumar*, Rui Liu, Taylor Lambert, Phillip Stahlman; Kansas State University, Hays, KS (1)

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

Reductions in Palmer Amaranth Groundcover Following an Auxin Herbicide Application.

Grant L. Priess*[1], Jason K. Norsworthy[1], Rodger B. Farr[1], Thomas R. Butts[2]; [1]University of Arkansas, Fayetteville, AR, [2]University of Arkansas System Division of Agriculture, Lonoke, AR (2)

In current and next-generation weed control technologies, sequential applications of contact and systemic herbicides for POST control of troublesome weeds are needed to mitigate the evolution of herbicide resistance. A clear understanding of the impact auxin herbicide symptomology has on Palmer amaranth is needed to optimize sequential herbicide applications. Field and greenhouse experiments were conducted in Fayetteville and a laboratory experiment was conducted in Lonoke, AR, in 2020 to evaluate changes in Palmer amaranth groundcover following an application of 2,4-D and dicamba with various nozzles, droplet sizes, and velocities. Field experiments utilized three nozzles: Extended Range (XR), Air Induction Extended Range (AIXR), and Turbo TeeJet Induction (TTI), to assess the effect of spray droplet size on changes in Palmer amaranth groundcover. Nozzle did not affect groundcover of Palmer amaranth when dicamba was applied. However, nozzle selection did impact groundcover when 2,4-D was applied; the following nozzle order XR>AIXR>TTI reduced Palmer amaranth groundcover the greatest in both site years of the field experiment. This result (XR>AIXR> TTI) matches percent spray coverage data and is inverse of spray droplet size data. Rapid reductions of Palmer amaranth groundcover from 35.9- to 60.6-percentage points and 14.2- to 39.2-percentage points were observed 180 minutes after application in greenhouse and field experiments, respectively, regardless of herbicide or nozzle. In one site-year of the greenhouse and field experiments, regrowth of Palmer amaranth occurred 10080 minutes (14 days) after an application of either 2,4-D or dicamba to larger than labeled weeds. In all experiments, complete reduction of live Palmer amaranth tissue was not observed 21 days after application with any herbicide or nozzle combination. Control of Palmer amaranth escapes with reduced groundcover may potentially lead to increased selection pressure on sequentially applied herbicides due to a reduction in spray solution contact with the targeted pest.

An EnlistDUO Systems Approach to Control Palmer Amaranth. Bradley J. Norris*[1], Jacob P. McNeal[1], Larry C. Walton[2], William J. Rutland[3], Darrin M. Dodds[1], Brian K. Pieralisi[4]; [1]Mississippi State University, Mississippi State, MS, [2]Corteva Agriscience, Tupelo, MS, [3]Mississippi State University, Starkville, MS, [4]Mississippi State University, Stoneville, MS (3)

Producers in Mississippi still continually battle to control Palmer amaranth (*Amaranthus palmeri*). The southeast is in much need of another mode of action to assist in Palmer amaranth control and the Enlist™ herbicide system allows for a mode of action to be POST applied. In 2020 a study was conducted in Tunica County to evaluate Palmer amaranth control utilizing various herbicide systems. They study was conducted using a randomized complete block design with four replications. Plots consisted of four 97-cm rows on raised beds (3.9 m wide by 6.1 m long). PhytoGen® PHY 390 W3FE was seeded at 111,000 seed ha^{-1} on May 20. Eight herbicide treatments consisted of combinations of herbicides such as 2,4-D choline, fluometuron, glufosinate, glyphosate, and S-metolachlor and three application timings A) PRE-B) POST 27 DAA and C) POST 20 DAB. Data were subjected to analysis of variance using the PROC GLM procedure in SAS v 9.4. Means were separated using Fisher's Protected LSD at a = 0.05. Twenty-three days after PRE application, fluometuron provided better overall Palmer amaranth control. In the end treatments having two or more modes of action, provided sequential Palmer amaranth control. In conclusion of this study Enlist™ herbicide system provides wonderful Palmer amaranth control.

Optimal Order and Respray Interval Using Glufosinate, 2,4-D and Dicamba for Waterhemp (*Amaranthus tuberculatus*) Control. Brent S. Heaton*[1], Alexis L. Meadows[2], Elaina M. Crawford[1], Mark L. Bernards[1]; [1]Western Illinois University, Macomb, IL, [2]Western Illinois University, Ames, IA (4)

The introduction of new herbicide-resistance trait stacks in soybean varieties has created new possibilities for sequential postemergence herbicides to control glyphosate-resistant waterhemp in soybean. Our objectives were to evaluate control of glyphosate-resistant waterhemp as influenced by: 1) the interval (4, 7, 14 or 21 days) between sequential applications of glufosinate, 2,4-D or dicamba in single herbicide-resistant systems, and 2) the sequence of glufosinate, 2,4-D and dicamba applied 14 or 21 days apart in glufosinate+2,4-D or glufosinate+dicamba trait systems. Field experiments testing objective 1 were conducted in 2019 and 2020, and an experiment testing objective 2 was conducted in 2020 on Western Illinois University farms in Macomb, Illinois. Herbicides were applied using a backpack sprayer. Visual ratings of waterhemp control were taken two and four weeks after the final application within a treatment. In 2020, weed counts and weed biomass were collected at four weeds after the final application within a treatment. Sequential applications of glufosinate or 2,4-D or dicamba always provided increased control relative to single applications of the herbicide at 28 DAT ratings. For 2,4-D and dicamba, waterhemp control was not affected the interval between applications. Glufosinate was less consistent: in one experiment the 4- and 7-day interval provided less waterhemp control than the 14- or 21-day intervals, and in a second experiment the 21-day interval provided less waterhemp control than the 4-, 7- or 14-day intervals. In experiments where two herbicides were used, waterhemp control was not affected by the sequence of herbicides nor by the interval between applications. 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. When glufosinate was applied first, waterhemp control was 89%, and when 2,4-D or dicamba were applied first, waterhemp control was 91%.

No Seed Means No Weeds or No Herbicide-Resistant Weeds. Taghi Bararpour*, Jason A. Bond, Henry M. Edwards, Jimmy D. Peeples; Mississippi State University, Stoneville, MS (6)

A field study was conducted in 2020 (second year) at the Delta Research and Extension Center, in Stoneville, Mississippi, to evaluate weed management strategies targeting glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) seed production and soil seedbank in Mississippi soybean. Soybean (CZ 4918 LL) was planted on May 19, 2020 and emerged on May 27. Plot size was 12 m [12 rows (1 m row^{-1})] by 9 m. There were 6 m alleys between each replication. Approximately 18,000 glyphosate-resistant Palmer amaranth seed were broadcasted per plot (in first year of the study in 2019) for uniform (as much as possible) Palmer amaranth population. The herbicide programs as follows: 1) glufosinate (Liberty) at V2-V3 soybean followed by (fb) V4-V6; 2) glufosinate at V2-V3 fb weed flowering; 3) glufosinate at V4-V6 fb weed flowering; 4) glufosinate at V2-V3 fb V4-V6 fb weed flowering; 5) glufosinate at V2-V3 fb weed flowering fb 14-20 days sequential; 6) glufosinate at V4-V6 fb weed flowering fb 14-20 days sequential; and 7) glufosinate at V2-V3 fb V4-V6 fb weed flowering fb 14-20 days sequential. A nontreated control was included. Before soybean harvest, two one-meter square samples of weed (from 4 center rows of soybean) were harvested (October 13) for recording number of plants, weed above-ground biomass and weed seed production by species per plot. Soybean yield from four-center rows was harvested at maturity (October 21). Glufosinate rate was 0.66 kg ai ha^{-1}. Glyphosate-resistant Palmer amaranth control was 98, 94, 78, 100, 99, 91, and 100% for herbicide program 1 through 7, respectively. Soybean canopy coverage was 76, 83, 65, 83, 84, 70, and 92% from herbicide program 1 through 7, respectively (by August 12). Also, the herbicide program 1 through 7 provided 70, 90, 83, 99, 100, 100, and 100% control of barnyardgrass (*Echinochloa crus-galli*); 71, 95, 96, 100, 100, 100, and 100% control of broadleaf signalgrass (*Urochloa platyphylla*); 94, 99, 98, 100, 100, 100, and 100% control of hemp sesbania (*Sesbania herbacea*); 99, 98, 94, 99, 100, 100, and 100% control of pitted morningglory (*Ipomoea lacunosa*); and 96, 98, 93, 99, 100, 100, and 100% control of prickly sida (*Sida spinosa*), respectively. Number of glyphosate-resistant Palmer amaranth present on October 13 was 0.04, 0.60, 0.25, 0, 0.01, 0.05, and 0 m^{-2} and above-ground dry weight was 0.15, 18.8, 5.9, 0, 0.1, 0.6, , and 0 g m^{-2} for herbicide program 1 through 7, respectively. The nontreated control had 1.4 m^{-2} glyphosate-resistant Palmer amaranth with above-ground dry weight of 240 g m^{-2}. Glyphosate-resistant Palmer amaranth seed deposition to the soil seedbank was 88; 2,592; 2,178; 0; 22; 113; and 0 seed m^{-2} from the application of herbicide program 1 through 7, respectively. Palmer amaranth seed deposition in nontreated control was 171,690 seed m^{-2}. Soybean yield was 3,596; 3,837; 3,262; 3,218; 3,217; 3,292; and 3,301 kg ha^{-1} for plots that received the application of treatment 1 through 7, respectively. The nontreated control yielded only 909 kg ha^{-1}. These results indicate that herbicide application at V2-V3 fb V4-V6 fb weed flowering fb 14-20 days sequential is necessary to stop glyphosate-resistant Palmer amaranth (and other weeds present) seed deposition to the soil seedbank 100%. The results indicate that stopping weed seed deposition to the soil seedbank or stopping/delaying the evolution of herbicide-resistant weeds and preserving the technology or the herbicides may be possible.

Industrial Hemp Sensitivity to Pre- and Post-emergence Herbicides. Lynn M. Sosnoskie, Elizabeth Maloney*; Cornell University, Geneva, NY (7)

Hemp is grown in many countries for its fiber, seed, and medicinal compounds, which are reported to be used in more than 25,000 products, collectively (Schluttenhofer and Yuan. 2017. Trends in Plant Science 22:917-929). Because of changes in the federal regulatory environment, specifically, the passage of the 2018 Farm Bill and the removal of hemp from the Controlled Substances Act of 1970, there is growing interest in hemp production in the United States (US). Because of its previous classification as a Schedule 1 narcotic, there is limited information regarding the management of pests in hemp. This includes the identification of herbicides that can be used in-crop, safely, for weed management. With few exceptions (e.g. Flessner et al. 2020. Crop Science 60:419-427), there is minimal information describing hemp tolerance to chemical weed control products. In 2020, preliminary greenhouse trials were undertaken to evaluate the response of a dual-purpose hemp cultivar to some POST herbicides registered for broadleaf weed control in New York. Hemp (cv 'Anka') seed were planted 1 cm deep in 7.6 cm diameter plastic pots filled with a commercial soil mix and grown in a greenhouse set to 26 C; supplemental lighting was applied to ensure a minimum daylength of 16 hours. Following emergence, seedlings were thinned 1 plant per plot. Herbicide applications were made at the 4- to 8-leaf stage of development. Treatments included: rimsulfuron, clopyralid, dicamba, prometryn, bentazon, bromoxynil, glyphosate, glufosinate, carfentrazone, fomesafen, and mesotrione. A non-treated check was also included for comparison. Each treatment was replicated up to six times for each of three runs of the full study. Herbicides were applied at rates commonly used in specialty and/or agronomic crops in New York and according to label instructions. Applications were made in a cabinet spray chamber (Allen Machine Works, Midland, MI) using a single TeeJet VS8002E nozzle (TeeJet Technologies, Springfield, IL). Irrigation was withheld for 24 hour following applications to ensure foliar herbicide absorption. At hemp injury was rated on scale of 0% (no crop injury) to 100% (complete crop death) every two days following treatment for 14 days. At 14 DAT, the aboveground plant biomass was harvested. Injury increased in most treatments from 2 to 14 DAT. Averaged across three runs, the least amounts of injury at 14 DAT were observed in the bromoxynil (13% injury, stunting and minor chlorosis) and the clopyralid (44% injury, elongated stems and leaf rolling) treatments. Mean per plant biomass, expressed as a percent of the untreated check, was greatest for bromoxynil (85%) followed by clopyralid (75%). These results agree with previously published work suggesting possible hemp tolerance to these active ingredients. Injury in all other herbicide treatments ranged from 85% to 100% and was characterized by bleaching, chlorosis, necrosis, and stem and leaf deformations. Mean plant biomass did not exceed 30% of the untreated check for the remaining herbicides. Studies to evaluate hemp sensitivity under field conditions to these and additional POST-applied chemicals will be undertaken in 2021. A single, preliminary greenhouse trial to evaluate hemp responses to PRE herbicides was also conducted in 2020, with the least amount of injury observed in the pendimethalin treatment. Studies are continuing in the greenhouse with respect to PRE herbicide tolerance screening.

Peanut Response to Diuron. Chad C. Abbott, Eric P. Prostko*, Taylor M. Randell; University of Georgia, Tifton, GA (8)

Diuron is frequently used for pre-plant burndown or preemergence weed control programs in cotton. Unfortunately, unintentional application and/or sprayer contamination events of diuron have occurred in Georgia peanut fields over the last few years. Limited research has been conducted on the effects of diuron on peanut. Therefore, the objective of this research was to determine the effects of diuron on peanut growth and yield when applied postemergence (POST). Irrigated, small-plot field trials were conducted in 2019 and 2020 at the UGA Ponder Research Farm near Ty Ty, Georgia. Twin-row 'GA-06G' peanuts were planted on April 30, 2019 and May 4, 2020. Treatments were arranged in a randomized complete block design with a 3 (timing) X 4 (rate) factorial arrangement with 3-4 replications. POST timing dates were 30 days after planting (DAP), 60 DAP and 90 DAP. Diuron 4L rates were 0, 4, 8 and 16 oz/A. Treatments were applied with a CO_2-powered backpack sprayer calibrated to deliver 15 GPA (40 PSI, 3.5 mph, 11002AIXR nozzles). The plot area was maintained weed-free using a combination of labeled herbicides and hand-weeding. Data collected included visual estimates of peanut leaf injury (chlorosis, necrosis), stunting, and yield. All data were subjected to ANOVA using PROC GLIMMIX and means separated using the Tukey-Kramer Method (P=0.10). Generally, POST applications of diuron caused various degrees of peanut injury in the form of leaf chlorosis/necrosis and overall plant stunting. These injury symptoms tended to increase with diuron rate. Peanut plants recovered from visual injury symptoms caused by earlier applications of diuron. For peanut yield loss, there was a significant interaction between time of application and rate. When applied at 30 DAP, diuron, at any rate, did not significantly reduce peanut yields. Yield loss was = 10%. When applied at 60 DAP, 4 oz/A caused a 24% yield loss, 8 oz/A caused a 28% yield loss, and 16 oz/A caused a 49% yield loss. When applied at 90 DAP, 4 oz/A caused a 25% yield loss, 8 oz/A caused a 38% yield loss, and 16 oz/A caused a 57% yield loss. Peanut growers must avoid unintentional applications of diuron especially later than 30 DAP.

White-Margined Flatsedge (*Cyperus flavicomus* Michx.): Controlling This New Problematic Weed in Arkansas Rice. Thomas R. Butts*[1], Tom Barber[1], Jason K. Norsworthy[2]; [1]University of Arkansas System Division of Agriculture, Lonoke, AR, [2]University of Arkansas, Fayetteville, AR (9)

A relatively new problematic sedge, white-margined or white-edge flatsedge (*Cyperus flavicomus* Michx.), has broadened its distribution across Arkansas and become increasingly troublesome to successfully control in rice. The objective of this research was to find key identification characteristics and effective control methods of white-margined flatsedge in rice. Two on-farm field trials evaluating burndown and preemergence residual herbicides and one greenhouse trial evaluating postemergence herbicides were conducted in 2020. From conducted research and field visits, the following identification characteristics were revealed. White-margined flatsedge is an annual with no rhizomes or nutlets, and no characteristic pine needle smell like that of rice flatsedge (*Cyperus iria* L.). Plants develop extremely white undersides on their leaves while keeping a green midvein; the tops of some leaves may also turn a silver-white color and the roots are a deep red. The base of the sedge plant has an extremely waterlogged, fleshy feel. Results from the herbicide evaluations revealed several viable options to successfully control white-margined flatsedge. Glyphosate and paraquat both provided greater than 95% control when applied in a burndown scenario to 5-cm tall plants. Thiobencarb and saflufenacil were the best preemergence herbicides for white-margined flatsedge control providing 88% and 86% control, respectively. ALS-inhibiting herbicides provided little control of white-margined flatsedge postemergence. Bentazon and florpyrauxifen-benzyl provided the greatest level of control postemergence (>90%) when applied to 15-cm tall plants. Overall, there are several viable options to successfully manage this weed species; however, proper identification and resulting herbicide selection paired with an appropriate application timing is key.

Acetochlor Use for Weed Control in Rice. Tristen H. Avent*, Jason K. Norsworthy, Leonard B. Piveta, Mason C. Castner, James W. Beesinger; University of Arkansas, Fayetteville, AR (10)

The evolution of clomazone-resistant barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] has driven Arkansas rice producers to pursue alternative sites of action for improved residual control early in the growing season. Acetochlor is a chloroacetamide herbicide which has demonstrated control of barnyardgrass, weedy rice (*Oryza sativa* L.), and other weedy grass species in rice. Acetochlor is currently not labeled in rice, partly due to variability in rice tolerance and stand loss at early application timings. Therefore, research was conducted to pursue a herbicide safener to use as a seed treatment to mitigate rice injury from chloroacetamides. To determine the weed control expectations provided by acetochlor and evaluate the safening effects of the seed treatment, field trials were conducted at the Rice Research and Extension Center near Stuttgart, AR in the spring of 2020. The experiment was a three-factor randomized complete block design which included a fenclorim seed treatment (0 and 2.5 g ai kg^{-1} seed), acetochlor application timings (preemergence (PRE), delayed-preemergence (DPRE), spiking, and 1-leaf), and microencapsulated acetochlor rates of (0, 630, 1,260, and 1,890 g ai ha^{-1}). As the rate of acetochlor increased, likewise injury and weed control increased. DPRE applications provided better barnyardgrass control than spiking and 1-leaf treatments, and at DPRE, acetochlor at 1,260 g ha^{-1} provided better weedy rice control than later applications. The fenclorim seed treatment did not influence weed control and reduced rice injury 21 days after each treatment from 33 and 54% to 13 and 20% for acetochlor rates of 1,260 and 1,890 g ha^{-1}, respectively. Furthermore, commercial tolerance was achieved at 1,260 g ha^{-1} DPRE, providing an average of 87% barnyardgrass control 21 days after treatment. These findings appear promising for the use of a fenclorim seed treatment in rice to safen microencapsulated chloroacetamide herbicides allowing chemistry not currently labeled in the crop in the U.S. to be safely applied.

Use Patterns of Bicyclopyrone in Minor Crops. Eric Rawls*[1], Peter Eure[2], Gordon D. Vail[3], Tom H. Beckett[3], Cheryl Dunne[1], Victor Mascarenhas[4], Henry McLean[5], Monti Vandiver[6], John Gordy[7], Tim Trower[8], Scott A. Payne[9]; [1]Syngenta Crop Protection, Vero Beach, FL, [2]Syngenta Crop Protection, Greensboro, NC, [3]Syngenta, Greensboro, NC, [4]Syngenta Crop Protection, Nashville, NC, [5]Syngenta Crop Protection, Perry, GA, [6]Syngenta Crop Protection, Vero Beach, TX, [7]Syngenta Crop Protection, Pearland, TX, [8]Syngenta Crop Protection, Oskosh, WI, [9]Syngenta Crop Protection, Slater, IA (11)

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.

Effect of Residual Herbicide Application Timing on Weed Management in 2,4-D- and Dicamba-tolerant Soybean. Daniel O. Stephenson, IV*; LSU Ag Center, Alexandria, LA (13)

Research has shown that residual herbicides are required for management of glyphosate-resistant (GR) weed species. Glyphosate-resistant Palmer amaranth (*Amaranthus palmeri* S. Watson) and waterhemp [*Amaranthus tuberculatus* (Moq.) J.D. Sauer] have been documented in Louisiana and are major pest in soybean. In addition, Louisiana soybean producers are also required to manage an average of two grassy weed and four broadleaf weed species in any given year. This broad weed spectrum encourages Louisiana soybean producers to utilize residual herbicides. However, the commercialization of 2,4-D- and dicamba-tolerant soybean has led to reduce the use of residual herbicides. The objective of the presented studies is to determine the effect of residual herbicide application timing in 2,4-D- and dicamba-tolerant soybean. Programs were evaluated separately in 2,4-D- and dicamba-tolerant soybean as a 3 x 3 factorial replicated four times. PRE residual treatments evaluated in both studies were flumioxazin at 0.07 kg ai ha^{-1}, premix of *S*-metolachlor plus metribuzin at 1.4 kg ai ha^{-1}, and no PRE. POST treatments in dicamba-tolerant soybean were glyphosate plus dicamba-BAPMA at 1.3 plus 0.56 kg ae ha^{-1} and pyroxasulfone at 0.09 kg ai ha^{-1} or *S*-metolachlor at 1.1 kg ai ha^{-1} plus glyphosate and dicamba. In 2,4-D soybean, POST treatments were the premix of glyphosate plus 2,4-D choline at 2.2 kg ae ha^{-1}, acetochlor at 1.3 kg ai ha^{-1} plus glyphosate and 2,4-D, and the co-application of *S*-metolachlor, glufosinate, and 2,4-D at 1.1, 0.7, and 1.1 kg ai or ae ha^{-1}. In dicamba-tolerant soybean, GR Palmer amaranth control was increased following flumioxazin or *S*-metolachlor plus metribuzin PRE 28 d after POST application. *S*-metolachlor plus metribuzin PRE provided greater control of barnyardgrass than flumioxazin and no PRE. Also, prickly sida control was increased following *S*-metolachlor plus metribuzin over no PRE. Following pyroxasulfone or *S*-metolachlor plus glyphosate and dicamba POST, barnyardgrass and hophornbeam copperleaf control was increased 28 d after POST application, but GR Palmer amaranth control was only increased following pyroxasulfone in dicamba-tolerant soybean. In 2,4-D-tolerant soybean, GR Palmer amaranth control was increased following flumioxazin or *S*-metolachlor + metribuzin PRE 28 d after POST application. However, like dicamba-tolerant soybean, *S*-metolachlor + metribuzin PRE provided greater barnyardgrass control than treatments without a PRE or containing flumioxazin PRE. The addition of acetochlor or *S*-metolachlor to the POST treatment increased control of barnyardgrass, GR Palmer amaranth, and hophornbeam copperleaf in 2,4-D-tolerant soybean 28 d after POST application. Based upon results, weed management programs in 2,4-D- and dicamba-tolerant soybean in Louisiana should contain a residual herbicide applied PRE following by a co-application with the non-selective herbicides POST in 2,4-D- and dicamba-tolerant soybean.

Reduction in DGA Dicamba Volatility as a Function of Potassium Tetraborate Tetrahydrate Concentration. Mason C. Castner*, Jason K. Norsworthy, Trenton L. Roberts, Leonard B. Piveta; University of Arkansas, Fayetteville, AR (14)

Labeled applications of the *N,N*-bis(3-aminopropyl)methylamine (BAPMA) salt of dicamba (Engenia) and diglycolamine salt of dicamba with VaporGrip (XtendiMax) have resulted in a record number of off-target complaints following introduction in 2017 for use as preemergence and postemergence control of broadleaf weeds in Xtend cotton and soybean systems. In efforts to reduce dicamba volatility, the University of Arkansas Division of Agriculture has pursued potassium tetraborate tetrahydrate (potassium borate) as a volatility reducing agent. Preliminary results from 2019 suggests that potassium borate has tremendous utility in mitigating dicamba volatility through buffering and ion scavenging potential. In 2020, small- and large-scale volatility studies were conducted to determine the optimal rate of potassium borate needed to reduce dicamba volatility. For low-tunnel evaluation, the diglycolamine (DGA) salt of dicamba plus potassium salt of glyphosate was applied in mixture with potassium borate at six concentrations (0, 0.00625, 0.0125, 0.025, 0.05, and 0.1 M) delivered at 140 L ha^{-1} to two moist flats placed under each tunnel. Treated flats, high-volume air samplers, and low-tunnels were removed from the field 48 hours after application. Regarding the three evaluated qualitative parameters (maximum soybean injury, average injury, and distance traveled), dicamba volatility was reduced as potassium borate concentration increased. Boron concentrations exceeding 0.025 M reduced dicamba movement by 2.7- to 3.4- m, respectively, compared to DGA dicamba plus glyphosate with no additive. High-volume air sampler data followed similar trends to qualitative assessments, with the least amount of total dicamba detected at the 0.05 and 0.1 M concentrations. As potassium borate concentration increased, the variability in detectable dicamba was likewise reduced. Overall, the addition of potassium borate to dicamba can effectively reduce dicamba volatility at rates sufficient to alleviate boron deficiencies.

Impact of Fall-seeded Cereal Rye Cover Crop on Pre-emergence Herbicide Fate and Grain-yield in Wisconsin Food-grade Soybean Production. Nicholas J. Arneson*, Ryan P. DeWerff, John Gaska, Brian Mueller, Shawn P. Conley, Damon Smith, Rodrigo Werle; University of Wisconsin - Madison, Madison, WI (15)

Fall seeded cereal rye (*Secale cereal* L.) used as a cover crop following corn (*Zea mays*) before soybean (*Glycine max* L. Merr) is once again becoming a common strategy to reduce soil erosion and suppress weeds. There is increased interest in terminating the cereal rye at or after soybean planting to maximize cover crop biomass; however, there is a concern that such practice may intercept PRE herbicides (which would in turn limit residual activity in the soil) and impact soybean yield. A field experiment was established at Arlington Agricultural Research Station, WI in 2019 and 2020 to evaluate the impact of termination timing on the fate of a residual PRE herbicide in the soil and grain yield of food grade soybean cultivars. The experiment was conducted in a RCBD (4 replicates) with a treatment factorial of 2 food grade soybean cultivars (Dane and MN1410) ? 3 termination timings [8 days before planting (DBP), at planting (0 DAP), and 14 days after planting (DAP)] ? 2 herbicide programs (no PRE and 0.15 kg ai ha^{-1} sulfentrazone + 1.38 kg ai ha^{-1} S-metolachlor) for a total of 12 treatments. The PRE herbicide treatment was sprayed at 0 DAP across all necessary treatments. Soil samples were collected 25 DAP and analyzed for persistence of sulfentrazone and S-metolachlor. Soybean grain yield were collected at crop maturity. Cereal rye termination timing had inconsistent effects on S-metolachlor and sulfentrazone concentrations; late termination with higher cover crop biomass did not necessarily result in lower herbicide concentration in soil as initially hypothesized. Cover crop termination timing did not impact soybean grain yield in 2019; however, 14 DAP termination timing resulted in slightly lower yield compared to 8 DBP in 2020 ($P<0.05$). PRE herbicide did not impact soybean grain yield in both years. Information presented herein provides baseline data for Wisconsin food-grade soybean producers who are considering adoption of cereal rye cover crop. More research is needed to better understand the factors that influence the potential impact of delayed termination of cereal rye on soybean yield.

Potential Burndown Options Before Cover Crop Establishment. Dwight Lingenfelter*, John M. Wallace; Pennsylvania State University, University Park, PA (16)

More farmers are adopting the use of cover crops for various reasons in the Mid-Atlantic region and other cropping systems of the U.S. Cover crops are typically established in the late summer or early fall to provide ground cover during the winter months and for other benefits to the soil and crop management. In some fields, weeds interfere with cover crop establishment. However, with glyphosate resistant weeds and potential crop injury from using higher rates of Group 4 herbicides, current and effective burndown herbicide options are limited prior to establishment of cover crops in the fall. A field study was initiated in 2020 in Pennsylvania (Rock Springs, Centre Co.) to examine the effects of commonly used burndown herbicides prior to fall cover crop establishment. Plots measuring 3m by 18m were established in a randomized complete block, split-plot design with three replications in a tilled seedbed. Herbicides were applied with a small-plot, CO2-backpack sprayer system that delivered 140 L ha^{-1} thru TeeJet AIXR110015 nozzles on September 8. Treatments included: 2,4-D ester (560 and 1120 gm ae ha^{-1}), dicamba (280 gm), halauxifen (5 gm), saflufenacil (25 gm ai), 2,4-D + saflufenacil (560 + 25 gm) and glufosinate (661 and 885 gm). Seven cover crop species – cereal rye (*Secale cereale*), annual ryegrass (*Lolium multiflorum*), forage radish (*Raphanus sativus*), crimson clover (*Trifolium incarnatum*), red clover (*Trifolium pratens*), hairy vetch (*Vicia villosa*), and alfalfa (*Medicago sativa*) were planted with a drill (4-5 rows each) at 0, 7 and 14 DAA across (perpendicular to) the treated areas. Overhead irrigation (1.25 to 2.5 cm) was implemented within two days of planting if adequate rainfall did not occur. Cover crop injury was visually evaluated approximately 9 WAA. Preliminary results from the late season rating indicate that crop injury varied between species, herbicide, and planting date. In general, cereal rye and ryegrass were impacted the least. Only 2,4-D (1120 gm) and dicamba caused 25% injury at 0d planting, while the other herbicides and planting dates resulted in less injury. Forage radish was injured most (20 to 73%) at 0d and 7d plantings by 2,4-D (560 and 1120 gm), dicamba, and 2,4-D + saflufenacil; however only 2,4-D (1120 gm) and 2,4-D + saflufenacil treatments at the 14d planting resulted in 28 to 50% injury. Crimson and red clovers were injured most (18 to 90%) by the Group 4 herbicides on 0d and 7d plantings, except halauxifen which caused no more than 12% crimson clover injury. The 2,4-D (1120 gm), dicamba, and halauxifen treatments still caused 22 to73% injury to red clover at 14d planting. Only dicamba and 2,4-D + saflufenacil treatments injured crimson clover the most (18 to 23%) at 14d planting. Hairy vetch was significantly injured (22 to 87%) by 2,4-D (both rates), dicamba, and 2,4-D + saflufenacil at 0d and 7d plantings, but only 2,4-D (1120 gm) and 2,4-D + saflufenacil treatments at the 14d planting resulted in 22 to 57% injury. Alfalfa was injured most (22 to 90%) by all the Group 4 herbicide-containing treatments across all planting dates, except 2,4-D (560 gm) at 14d which only caused 8% injury. Saflufenacil and glufosinate did not cause significant injury to any of the cover crops at any of the planting dates. In summary, the use of Group 4 herbicides as a burndown treatment prior to fall cover crop establishment tend to be risky. However, depending on what species is selected (e.g., cereal rye or ryegrass) and when it will be planted (>7 DAA) some Group 4 herbicide options could still be useful. Furthermore, from this preliminary data, other herbicides such as saflufenacil and glufosinate might have a fit since they are generally safe to many cover crop species and can control problematic weed such as glyphosate-resistant horseweed and Palmer amaranth. These could be tankmixed with glyphosate for broad spectrum burndown prior to cover crop establishment. Additional data will be collected from this study during the spring and further research will need to be conducted at this and other locations to verify the results.

Survey of California Weedy Rice (*Oryza sativa* f. *spontanea*) Acreage: Infestation Patterns and Severity. Whitney Brim-DeForest*[1], Luis Espino[2], Troy Clark[2], Timothy Blank[3]; [1]University of California Division of Agriculture and Natural Resources, Yuba City, CA, [2]University of California Division of Agriculture and Natural Resources, Oroville, CA, [3]California Crop Improvement Association, Davis, CA (17)

Weedy rice (*Oryza sativa* f. *spontanea*) was found in California on a large scale in 2016, about 4000 hectares over 8 counties, after having been only found in a few fields in one county previously. Acreage was updated in 2017-2019 with newly infested fields, to a total of approximately 5600 hectares in 2019, but acreage maps were not updated to reflect previously-infested fields where weedy rice populations had changed. A survey was conducted from June 2020 thru September 2020 on 4300 acres across 8 counties (Glenn, Butte, Colusa, Sutter, Yolo, Yuba, Placer and Sacramento) in Northern California. The acreage was less than previously recorded in 2020, due to coordination with growers, who had to be asked for permission before entering field locations. The survey process entailed coordinating with growers and discussing site history, visually inspecting, and rating each basin (within a field), collecting samples, potassium hydroxide (KOH) testing of grains, and creating maps by hand and Global Information Systems (GIS). Each field was surveyed on an individual basin level. Each basin was surveyed by patrolling the parameter and visually and physically inspecting. In some cases, binoculars were used to scan the field. Four techniques were used to distinguish weedy rice plants from the cultivated varieties: 1) the suspected weedy rice was visually identified as taller than the canopy of the cultivated variety; 2) to distinguish the plant from common watergrass species the ligule was located; 3) the pubescence of the leaf was felt by rubbing with the index finger and thumb from the tip down to the base of the leaf; and 4) both panicle and grain color were assessed visually and chemically. Potassium-hydroxide (3%) was used to stain the pericarp on the grain from the suspected weedy rice plants. Grains from known cultivated varieties were used as controls. Weedy rice grains stained red, while cultivated varieties showed no color change. In some cases, where field identification could not verify the presence of weedy rice, samples of the entire suspected plants were taken from the fields and grown to heading in the greenhouse (many of the unknown samples were collected before heading). All known biotypes (1 to 7) were recorded. Once the weedy rice was identified in the field, a rating system was used to assess the level of the infestation from 0 to 6, with 0 being the absence of weedy rice, and 6 being 25% or more of the field infested. The rating system was applied to each basin. Results indicated that 20.7% of the basins surveyed contained weedy rice. Of those basins that contained weedy rice, 21.1% were rated at infestation level 1 (less than 10 individual plants), 27.4% were rated at infestation level 2 (more than 10 individual plants), 34.7% were rated infestation level 3 (less than 5 patches of plants), 10.5% were rated infestation level 4 (more than 5 patches of plants), and 6.3% were rated infestation level 5 (10-25% of the basin infested). There were no basins rated at infestation level 6 (more than 25% of the basin infested). In terms of biotype distribution, 54.5% of the fields contained Biotype 1, 30.9% contained Biotype 2, 13.1% contained Biotype 3, 0.6% contained Biotype 4, and 0.9% contained Biotype 4. No fields were found with Biotype 5 or Biotype 7.

Airborne Hyperspectral Imaging to Classify Different Desiccants Performance in Lentil (*Lens culinaris*) Crop. Keshav D. Singh*, Eric N. Johnson, Hema S. Duddu, Steve J. Shirtliffe; University of Saskatchewan, Saskatoon, SK, Canada (18)

The application of herbicides in agriculture has significantly increased in last few decades. Most of the growers rely on desiccants to dry down the crop before harvest. It is important for growers to identify the right herbicide and optimal spraying that do not imperil their lentil quality. Therefore, it is needed to find a quicker non-invasive way to evaluate the response of different desiccants. The main objective of this study was to explore the potential of aerial imaging to measure herbicidal responses to dry down the lentil crop. Here, we have used the hyperspectral imaging (HSI) technique to accurately dissect the response of desiccants on lentils at different DAT (days after treatment). A small experimental trial (32 RCBD plots) of red lentil variety (CDC Maxim) consisting of five conventional herbicides (Glyphosate 900g, Saflufenacil 36g, Glyphosate Heat 900g+36g, Glufosinate 400g, Reglone (diquat 296g) @ ai/ha), one organic herbicide with 2 rates (Ammonium Nonanoate 20% and 32.5% v/v), and an untreated check (control) were used in this study. The desiccation visual drydown rating (DESICC: 0-100%) and plant moisture content (MOISCON %) were measured at five time-points as 0(baseline), 3, 7, 10, and 24 DAT. A UAV-based Corning® microHSI™ camera was used to collect hyperspectral imagery (400-1000nm) on the same day of visual ratings. The spectral data of herbicide treatments were analyzed using partial-least-squares discriminant-analysis (PLS-DA) to calculate desiccation response scores for all the time-points and Euclidean distance approach was used to measure the treatments effect with time. Of all the treatments, ammonium nonanoate has produced a rapid desiccation effect (starting from 3DAT). Greater Euclidean distances from the control treatment were observed for both the rates and the corresponding visual desiccation ratings were above 80% at this time-point. Among the conventional herbicides, Reglone found to be most effective on account of greater Euclidean distances that aligns well with the visual ratings. Other desiccants effect starts slowly throughout. Alongside, out of all vegetation indices calculated, canola maturity index (CPMI) was found to be strongly correlated ($p<0.05$) with the desiccation rating (R^2=0.60-0.97). It was also observed that there is a strong relationship between spectral data and plant moisture, which can be used in estimating the desiccation timing. The obtained results endorse the developed hyperspectral imaging methodology can be used as a reliable tool in herbicide screening programs.

Impact of Weedy Invasion on Subsistence Agriculture and Pasture Degradation of Cold Arid Region of Ladakh India. Mahendra Singh Raghuvanshi*[1], Stanzin Landol[2], Mohammad Raza[2], Ngawang Dorje[2]; [1]ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur, India, [2]RRS, ICAR-Central Arid Zone Research Institute, Leh-Ladakh, Leh-ladakh, India (19)

Himalayan High Altitude Wetlands are the unique ecosystems of the world, supporting a wide variety of flora/ fauna, providing valuable pastures to the local communities who are dependent upon livestock and also the sources of various rivers, originating from the region. Ladakh, the cold desert located in NW Himalayas has a number of high altitude wetlands and pastures that are now facing high degree of degradation due to desiccation, salinity, feeding pressure and invasion by exotic weedy species. Conceptualization of investigation revealed the outcome of bio-physical survey on invasiveness of *Phragmites* and *Cirsium arvense* in cropped areas in and around Thiskey, Palam, Lower Saboo, Stakna, Spituk and Chushot villages of Leh district and pastures of Changthang region due to ignorance of farming community for weedy fodder demand is the major cause of for decreased crop yield and plant biodiversity. While making survey, villages have apparently been bypassed by most weedy endemics and explorations which enabled to understand the weedy menaces and their importance as fodder too. Reason of weedy presence in cropped areas is directly proportionate high costs of labourers during cultivation. The study made a basic inventory of frost heave patterned grounds in cold arid desert of Leh and found typical growth and association of weeds on such surfaces that are known to reduce the survival of palatable plant or grasses. Farming first time were exposed towards the weedy impact and their traditional uses in their day to day livelihood. Their timely control enhanced the crop yield and health of pastures.

Field Pennycress (*Thlaspi arvense*) Response to Herbicides Applied Postemergence. Kevin Betts[1], M. Scott Wells[1], Debalin Sarangi[1], Mark L. Bernards*[2], Donald L. Wyse[1]; [1]University of Minnesota, St. Paul, MN, [2]Western Illinois University, Macomb, IL (20)

Field pennycress is being developed as multi-purpose crop. Oil extracted from the seed will serve as a feedstock for aviation biofuel, meal will be processed for animal feed, and pennycress will provide green soil cover through the winter between a small grain (where growing seasons are short) or corn (where growing seasons are longer) and a subsequent soybean crop. Winter annual weeds can compete with pennycress reducing seed yield and contaminating harvest. The moist, green vegetation of early emerging summer annual weeds can also interfere with pennycress harvest (mid-May to early-June) and no-tillage soybean establishment following harvest. Identifying herbicides that may be safely used postemergence in pennycress as potential tools for managing weed infestations will be important tools for prospective growers of this new crop. Our objective was to evaluate pennycress injury and yield with spring-applied herbicides when plants were still in the rosette stage (pre-bolt) or in the early stages of stem-elongation (early-bolt). Pennycress was planted in September of 2016, 2017, 2018 at the University of Minnesota's Rosemount Research and Outreach Center. Experiments were arranged in a randomized complete block design with three replications. Thirty-seven different herbicides labeled for use in corn or soybean were tested, some were applied at only one growth stage (pre-bolt or early-bolt), but others at both stages. Herbicides were applied using a bicycle sprayer between late-April and mid-May (2017, 2018 and 2019), depending on growing degree accumulation and pennycress growth stage. Pennycress yields were severely reduced (greater than 50%) by most of the herbicide treatments at both pre-bolt and early-bolt application times. Herbicides tested from Group 2 (ALS-inhibitors), Groups 5 & 6 (Photosystem II-inhibitors), Group 14 (PPO-inhibitors), Group 27 (HPPD-inhibitors) all caused severe injury and yield loss. Herbicides from Group 15 (Very long-chain fatty acid synthesis inhibitors) and Group 3 (Microtubule assembly inhibitors) were applied only at Pre-bolt and caused minimal-to-no injury and yield loss, with the exception of pyroxasulfone, which was inconsistent across years (no yield loss to greater than 50% yield loss). Pennycress response to Group 4 (Auxin mimics) was inconsistent: 2,4-D and fluroxapyr always caused severe yield loss, dicamba caused moderate-to-severe yield loss, 2,4-DB caused no loss up to severe yield loss, and clopyralid caused no-to-moderate yield loss. Herbicides from Group 15 and clopyralid are the most promising herbicidal candidates for managing spring weeds in pennycress.

Evaluation of Herbicide Programs in Oklahoma Soybean. Todd A. Baughman*, Zachary R. Treadway, Robbie W. Peterson; Oklahoma State University, Ardmore, OK (21)

Weed resistance has forced producers to rely on many different weed management plans. One method is using LibertyLink technology for controlling these resistant weeds. Unfortunately, due to the dry environment, Oklahoma soybean producers often experience inconsistent results with this technology. This results in creativity in tank-mix options. This has led to some questions about the efficacy and potential soybean injury concerns with these tank mixes. Soybean weed management trials were conducted at the Oklahoma State University Mingo Valley Research Station near Bixby, OK; during the 2019 and 2020 growing seasons. LibertyLink® soybean technology was planted in early June of each year. Liberty (glufosinate) was applied at 32 fl oz/A either POST1 + POST2 or POST2 + POST3. Liberty was either applied alone or in various combinations with Moccasin II Plus (metolachlor) at 16 fl oz/A, and/or ammonium sulfate at 2 lb/A. All treatments included Induce (non-ionic surfactant) at 0.25 % v/v. Visual soybean injury was 5% or less with all treatments both years except for Liberty + Moccasin II Plus + ammonium sulfate POST 2 + 3 in 2019. When only one application of Liberty was made Palmer amaranth (AMAPA), large crabgrass (DIGSA), and ivyleaf morningglory (IPOHE) control was at least 90% when applied POST1 compared to less than 80% POST2 in 2020. Similar results were observed for AMAPA in 2019. AMAPA control in 2019 and 2020 was at least 90% 10 WAP when POST1 and POST2 applications were followed by a second application of Liberty. AMAPA control was 100% when Liberty was applied POST 1 + 2 in combination with Moccasin II Plus both years. DIGSA and IPOHE control was at least 95% in 2020 with two applications of Liberty regardless of tank-mix partner or initial timing. All Liberty POST 1 + 2 treatments yielded at least 50 bu/A, while all Liberty POST 2 + 3 yielded less than 50 bu/A in 2020. This was likely due to the early season weed competition due to the first POST application being delayed in the POST 2 + 3 treatments. Interestingly, yields exceeded 50 bu/A with all treatments in 2019. The only treatment where delaying the first application to POST 2 reduced yields was with Liberty + Moccasin II Plus + Induce in 2019. This research indicates that depending on year, soybean yields can be reduced by delaying the first post application. Growers should also consider if weather had delayed any of these applications, weed control most likely would have been reduced.

Identification of Soybean Lines That Have Differential Sensitivity to Dicamba. Matthew Osterholt*[1], Scott McAdam[1], Katy Rainey[1], Caio Canella Vieira[2], Pengyin Chen[2], Bryan G. Young[3]; [1]Purdue University, West Lafayette, IN, [2]University of Missouri, Portageville, MO, [3]Purdue University, Brookston, IN (22)

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 included 230 soybean lines and identified two divergent groups following dicamba drift that occurred at their research sites: relatively low and high sensitivity soybean lines. Identifying soybean lines that have lower sensitivity to dicamba could offer a unique opportunity to develop soybeans varieties that can minimize the impact of commercial off-target dicamba movement and provide a more academic benefit of providing a well-established soybean genome as a test species to 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 to 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 plant 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. 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.

IR-4: Weed Control Project Updates - Food Crops. Roger B. Batts*[1], Jerry J. Baron[1], Daniel L. Kunkel[2], Michael P. Braverman[2]; [1]IR-4 Project HQ, NC State University, Raleigh, NC, [2]IR-4 Project Headquarters, Princeton, NJ (24)

In 2020, IR-4 data led to just under 600 new uses. This number was quite a bit lower than most years. Twenty of these uses are for herbicides and plant growth regulators (including prohexadione calcium, sethoxydim, s-metolachlor, isoxaben, saflufenacil and 2,4-D) in a wide range of crops (alfalfa, globe artichoke, caneberry subgroup, hops, dill, rosemary, fig, chia, basil, sesame and intermediate wheatgrass). Also in 2020, IR-4 data petitions were submitted to EPA for ethalfluralin/stevia, glufosinate/fruiting vegetables, curcurbits, fig, avocado and hops, 2,4-D/clover and floransulam/grasses grown for seed. Along with these direct requests, these petitions also included request for several crop group conversions and crop group expansions for these compounds. Sixteen new herbicide magnitude-of-residue studies began in 2020. The number of on-going herbicide Product Performance studies in 2020 was twenty. Development of Product Performance data (efficacy and crop safety research) to support labeling of new uses for specialty crop pest management tools continues to be an important priority in the IR-4 Project's annual research plan as the data are often required by registrants and states (e.g.California) to complete the registration process. The 2021 field research plan for herbicides and plant growth regulators includes fifteen residue studies and twenty-two continuing or new Product Performance studies. The recently-established IR-4 Integrated Solutions Program is designed to address pest problems without solutions, resistance management, products for organic production and pesticide residue mitigation. Five new weed control Integrated Solutions studies will also begin in 2021, bringing the list of active Integrated Solutions weed control studies to seven. These projects are addressing need in grapes, apples, blueberries, processing tomatoes, sweetpotatoes, haskap, and date palm. The transition of IR-4 Headquarters to NC State University continues, but was slowed for various reasons during 2020. This relocation should be completed by September 2021

Canada Thistle Control in Hop with a Sponge Wiper Application of Clopyralid. Marcelo L. Moretti*, David R. King; Oregon State University, Corvallis, OR (25)

Canada thistle (*Cirsium arvense*) is a pernicious weed in hop fields (*Humulus lupulus*). Clopyralid is used to manage Canada thistle, but application methods that reduce potential crop injury or drift are needed. The objective of this study was to compare the efficacy, application timing and costs, and residue levels in the crop of clopyralid applied as a broadcast or with a sponge-wiper. Two studies were conducted in commercial hopyards located in Oregon between 2019 and 2020. Canada thistle control with a clopyralid broadcast application (0.27 kg ai ha^{-1}) was comparable to the sponge-wiper application (2 % vol/vol). Sequential treatments of clopyralid at rosette and bolt stage provided more consistent control of Canada thistle than single applications made at either stages. Cost of sponge-wiper application of clopyralid was calculated at about \$52 ha^{-1}, about half the cost of broadcast application. Both application methods were safe to hop plants and resulted in similar residue levels, which averaged 0.014 ppm - well below the maximum allowable residue level of 5 ppm of clopyralid. Clopyralid applied with sponge-wiper is a cost-effective alternative to broadcast application and can mitigate concerns of drift without negatively impacting residue levels.

Response of Sweetpotato Cultivars to Dicamba and 2,4-D. Ziming Yue*[1], Isabel S. Werle[2], Steve L. Meyers[3], Mark W. Shankle[4], Te-Ming (Paul) Tseng[1]; [1]Mississippi State University, Mississippi State, MS, [2]University of Arkansas, Fayetteville, AR, [3]Purdue University, West Lafayette, IN, [4]Mississippi State University, Verona, MS (26)

Sweet potato (*Ipomoea batatas* (L.) Lam.) is the seventh most important food crop in the world.It can produce more edible energy per hectare per day than other C3 crops such as wheat, rice, and cassava. Mississippi annually grows 28,000 to 30,000 acres of sweet potatoes and ranks No. 3 after North Carolina and California by USDA. Weed competition and interference can reduce sweet potato yield by 40-90%. In Mississippi, the yield reduction due to weeds can reach up to 81%. Early-season competition and interference from weeds, especially the first six weeks after transplanting, are extremely critical. The standard weed management methods include manual weeding, mechanical and chemical methods. The limitations of the first two methods make the chemical methods necessary. However, the chemical methods are limited by few options of herbicide. Clomazone alone is not effective on Palmer amaranth, flumioxazin controls Palmer but not nutsedge, and S-metolachlor is effective on Palmer and nutsedge but also reduces yield and quality. Most herbicides are limited to wick on row-middles but not spray within rows. Previous research focused on herbicide selection, application rate, timing, and application methods; herbicide tolerance has not been evaluated in sweet potato. This project evaluated tolerance of selected sweet potato cultivars to dicamba and 2,4-D with the long-term goal of developing a practical weed control program for sweet potato in Mississippi. The experiments included two steps: first, 0.1-1X dicamba and 0.1-1X 2,4-D were used to screen the survivors among 20 sweet potato cultivars; second, 0.4X dicamba and 0.2X 2,4-D were used (based on step 1 results) to evaluate the response contrast between the tolerant cultivars and Palmer amaranth seedings. The results showed the tolerant sweet potato cultivars and Palmer amaranth had contrast response to both dicamba and 2,4-D, suggesting dicamba and 2,4-D can be used for in-row application on sweet potato. By combining herbicides with other modes of action, a practical weed control program can be achieved for these sweet potato cultivars.

Table Beet Response to Simulated Carryover of HPPD Herbicides. Lynn M. Sosnoskie*, Elizabeth Maloney; Cornell University, Geneva, NY (27)

Some New York growers are rotating table beets with agronomic crops to reduce disease pressure from root rot pathogens. Rotating with commodities like corn may also have positive impacts with respect to weed management (e.g. because of increased diversity of chemical tools). However, herbicide carryover between crops can result in economic losses due to chemical injury; in a corn-beet rotation, damage from mesotrione (and other HHPD-inhibiting herbicides) is a significant concern. Plant back restrictions to sugar beets following mesotrione applications are lengthy to minimize the potential for crop damage; discussions with New York producers indicate that table beets are similarly intolerant of mesotrione residues. In 2020, preliminary greenhouse trials were undertaken to describe table beet responses to a range of mesotrione doses. The studies were conducted using a Honeoye loam; the Honeoye series occurs on 500,000 acres in New York and is the state soil. Fifteen multi-germ 'Ruby Queen' seed balls were planted 2 cm deep in 7.6 cm diameter pots that were randomly assigned soil treatments of 0, 1.1, 2.1, 10.5, 21, 105, and 210 g ai ha^{-1} mesotrione that was thoroughly incorporated throughout the soil profile. Each treatment was replicated 6 times in each of two runs of the study. Pots were watered so as to prevent herbicide leaching. Emerged and unbleached beet seedlings in each pot were counted at 14 DAT. A second study which included soil-applied treatments of mesotrione at rates of 0, 0.11, 0.21, 1.1, 2.1, 10.5, 21, 105, and 210 g ai ha^{-1}, was also conducted; beet emergence, as well as plant biomass, were assayed at 14 DAT. Table beet injury to mesotrione was characterized by bleaching followed by necrosis starting at 2 to 3 DAT; surviving plants were often stunted depending on treatment rate. Results from the first trial indicated that table beets establishment was significantly affected by all rates of mesotrione. In the first study, a mean of 14 and 11 beet seedlings emerged per pot in the untreated checks in the first and second runs, respectively. Successful beet emergence was reduced by all other rates of mesotrione; mean emergence ranged from 0 to 12.3% for rates of 210 to 2.1 g ai ha^{-1} across both runs of the study. Mean beet emergence at 1.1 g ai ha^{-1} was 37% in run 1 and 31% in run 2. In the second study, mean per pot emergence ranged from 0% at the three highest mesotrione doses to 1% at 10.5 g ai ha^{-1}, 19% at 2.1 g ai ha^{-1} , and 66% at 1.1 g ai ha^{-1}. At mesotrione rates of 0.11 and 0.21 g ai ha^{-1}, mean per pot beet emergence exceeded 90%, although per plant beet seedling biomass (0.13 to 0.20 g) was lower than the check plants (0.20 to 0.27 g). Results from this study will be used to develop field-based trials to 1) evaluate the impacts of simulated residue carryover of HPPD-inhibiting herbicides on table beets and to 2) describe potential interactions between HPPD-inhibiting herbicides and soil-applied herbicides labeled for weed control in beets.

Cabbage/Cauliflower Tolerance to Pyridate Formulations. Sushila Chaudhari*, Bernard H. Zandstra, Monique Hemker; Michigan State University, East Lansing, MI (28)

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.

Evaluation of Weed Control Efficacy and Plant Safety of Selected Herbicides for Bearing Avocado (*Persea americana*). Peggy Mauk[1], Sonia I. Rios*[2], Ben Faber[3], Oleg Daugovish[3], Dee L. Vega[3], Travis Bean[4]; [1]University of California - Riverside, Riverside, CA, [2]University of California, Division of Agriculture and Natural Resources, Moreno Valley, CA, [3]University of California, Division of Agriculture and Natural Resources, Ventura, CA, [4]University of California, Division of Agriculture and Natural Resources, Riverside, CA (29)

Currently there are 10 herbicide active ingredient groups registered for use on bearing avocado *(Persea americana* Mill.*)* groves in California (CA). Of these, paraquat is a restricted use herbicide and glyphosate is under increasing political scrutiny. To provide more chemical options, we conducted a study to evaluate the phytotoxicity and efficacy of several herbicides, currently registered in citrus, in bearing avocado. Herbicides applied in fall or spring were evaluated on bearing avocado trees at two of the major avocado growing regions, Riverside and Santa Paula, CA. Treatments included: caprylic/capric acid, clethodim, flumioxazin, glufosinate, glyphosate, indaziflam, isoxaben, oxyfluorfen, pendimethalin, rimsulfuron, salfufenacil, simazine, s-metolachlor, and an untreated control. All herbicides were applied without surfactants. Herbicide applications were made using calibrated CO_2 backpack sprayer using the rates and carrier volumes listed on labels for citrus. Following treatment applications, the pre-emergence herbicides were incorporated using temporary sprinkler systems to simulate 0.5 inch of rainfall. Weeds at the Riverside location were 2-4 inches tall at the time of application. The primary weeds species in the plots were *Amaranthus albus* (tumble pigweed), *Portulaca oleracea* (common purslane), *Sonchus hierrensis* (sow thistle), *Malva parviflora* (little mallow), and *Urtica urens* (burning nettle). Although not a predominant weed species, *Erigeron bonariensis* (Hairy fleabane) was also found sporadically throughout the orchard. Weed mortality based on herbicide a.i. and phytotoxicity to avocados were monitored at 1, 2, 4, and 8 weeks after treatment (WAT) during the fall and spring. Glufosinate and glyphosate, controlled 95-100% of the weeds for up to 8 WAT in both seasons. However, in the fall treatment, glufosinate and glyphosate caused significant phytotoxicity. The avocado tree foliage showed 71 and 75%, injury, with glufosinate and glyphosate, respectfully. In the spring application, glufosinate caused phytotoxicity (up to 50%) at 2 WAT, whereas phytotoxicity from pendimethalin, isoxaben and saflufenacil (29, 38, and 23% respectively) was evident only at 8 WAT. The plants overcame the injury from glufosinate as the levels declined to 15% at 8 WAT. Indaziflam also gave excellent weed control in the fall and spring with some minor phytotoxicity to the foliage in the first weeks after application, however, phytotoxicity symptoms diminished to 15% by 8 WAT. Rimsulfuron, similarly, had exceptional weed control in the both spring and fall throughout 8 WAT and exhibited little to no phytotoxicity to the avocado foliage. Ratings from the Santa Paula for fall 2019 and spring 2020 applications were inconclusive Our study indicated that indaziflam and rimsulfuron have good potential for weed control in bearing avocado. Similarly, glyphosate and glufosinate also provide excellent control but can have phytoxicity concerns in bearing avocado orchards.

Developing a Decision-Support Tool for Facilitating the Selection of Diverse Herbicide Mode of Action in Turf. Vanaja Kankarla*[1], Edicarlos Batista de Castro[2], Jay McCurdy[2], Daniel Hathcoat[1], Rebecca Bowling[3], Muthukumar V. Bagavathiannan[1]; [1]Texas A&M University, College Station, TX, [2]Mississippi State University, Mississippi, MS, [3]Texas A&M University, Dallas, TX (30)

Turfgrass is one of the most widely grown and economically important specialty crops in the United States, spanning across approximately 50 million acres. Major industry sectors include golf courses, athletic/sports fields, sod production, and residential lawns. Annual bluegrass (*Poa annua* L.) is a troublesome weed across all industry sectors, costing many millions of dollars in control expenses, decreasing utility and playability, and contributing to lost aesthetic value. Herbicide resistant annual bluegrass is a serious concern. An important best management practice to avoid herbicide resistance is the use of diverse herbicide modes of action in rotation, sequence, and mixture. A web-based decision-support tool is being developed to facilitate the selection of diverse herbicide modes of action by turfgrass managers targeting annual bluegrass. This tool includes a database of different herbicide options available for controlling annual bluegrass in various turfgrass systems, their use rate, and control efficacies. A risk model evaluates the risk of weed resistance to the herbicide program selected by the user and provides appropriate feedback to facilitate the selection of robust management options. The model also considers herbicide use history and the potential of suspected or confirmed herbicide resistance in a given population. The tool will educate stakeholders and support decisions regarding best management practices.

Potassium Application Impacts *Andropogon* Densities in Bahiagrass (*Paspalum notatum*) Pastures. Brent A. Sellers*, Maria L. A. Silveira; University of Florida, Ona, FL (31)

Broomsedge (*Andropogon*) species are native, warm-season, short-lived perennial bunchgrasses with an average life span of 3 to 5 years. While some species are desirable in many natural areas and native rangeland, they are becoming problematic in improved bahiagrass pastures throughout central and south Florida as mature broomsedge is typically avoided by cattle. Management tactics in other areas of the U.S. have indicated that increasing soil fertility through lime or macronutrient application has resulted in a decrease in broomsedge density, with phosphorus being implicated in much of the research. However, subsoils P levels in Florida are relatively high and application of P is no longer recommended in bahiagrass pastures without tissue testing in conjunction with soil testing. This research was conducted to determine which soil amendments are responsible for reducing broomsedge populations in bahiagrass pastures as well as to determine which macronutrient may be responsible. Two experiments were conducted. The first experiment was initiated in 2012 at three locations on three different broomsedge species: Arcadia (bushy bluestem; *Andropogon glomeratus* (Walter) Britton et al.), Ona (purple bluestem; *Andropogon glomeratus* (Walter) Britton et al. var. *glaucopsis* (Elliott)C.Mohr), and St. Cloud (broomsedge bluestem; *Andropogon virginicus* L. var. *virginicus*). Following soil testing, treaments included: 1) Lime or annual elemental S (112 kg ha^{-1}) applications vs. untreated, 2) N + P + K (56 + 28 + 56 kg ha^{-1}) vs. untreated, and 3) a micronutrient blend (Frit 503G; 28 kg ha^{-1}). With the exception of lime all soil amendments were applied annually; lime was applied only as needed as suggested through soil testing. The experimental design was a factorial arrangement of treatments in a randomized complete block with 4 replications; individual plots measured 30 x 30 m. The second experiment was initiated in 2017 at two locations containing primarily broomsedge bluestem near Ona and Lake Placid. Lime was applied as needed to each location prior to macronutrient treatments: 1) N (56 kg ha^{-1}), 2) P (28 kg ha^{-1}), 3) K (56 kg ha^{-1}), 4) N + P, 5) N + K, 6) P + K, 7) N + P + K, and 8) untreated. The experimental design and plot layout was as described above. Broomsedge densities were recorded from 4, geo-referenced locations in each plots annually within a 3 m diameter area. Initial broomsedge densities were utilized as a covariate for analysis; means were separated using Tukey's HSD when appropriate. A reduction in bushy bluestem density was observed following one year of NPK application at the Arcadia location; a 16% reduction in density was recorded in plots receiving NPK. Over time, bushy bluestem density continued to decline in both untreated and treated plots and was at least 36% lower from 2014 through 2020, except for 2017; this decline could be attributed to annual mowing. Application of elemental S had no effect on bushy bluestem density, but has began decreasing soil pH from 7.8 to near 6.0 after 5 years of application. Purple bluestem density was not impacted by soil amendments until 2015 when the 2012 lime application resulted in a 55% reduction compared to non-limed plots. Liming at the appropriate rate has resulted in at least a 64% reduction in purple bluestem density since 2016; this location has also been mowed annually. Broomsedge bluestem densities near St. Cloud have not been affected by soil amendments since 2012; this site has not been mowed consistently. Potassium application in the second experiment is the only macronutrient shown to decrease broomsedge densities by as much as 74% within three years of the first annual application. No other macronutrient has resulted in a decrease in broomsedge density. Overall, there is not a consistent treatment for all broomsedge species for optimum management, and the identification of individual species may be important to make the appropriate management decisions in Florida.

Effect of Mowing Timing on Johnsongrass Herbicide Efficacy: Three Years of Trials. Joe Omielan*, Michael Barrett; University of Kentucky, Lexington, KY (33)

Johnsongrass (*Sorghum halepense*) is a perennial warm season grass, listed as a noxious weed, and a common problem on right-of-way sites. There are a number of herbicides labeled and available to control johnsongrass and most rely on translocation from the leaves to the rhizomes for greatest efficacy. However, mowing is part of roadside management and one question is how does the timing of mowing after herbicide application affect efficacy? This study was initiated August 14, 2014 and repeated August 24, 2015 to answer the questions asked above at an interchange near Bardstown KY. It was repeated August 30, 2019 on a field in Lexington. Four herbicide treatments were applied to applied to 3 m x 18 m strips at 280 L/ha. Six time of mowing treatments were applied as 3 m x 12 m strips across the herbicide treatments in a split block design, replicated three times (four times in 2015 and 2019). The herbicide treatments were Outrider (sulfosulfuron), Fusilade II (fluazifop), Acclaim Extra (fenoxaprop), and Fusilade + Acclaim. The time of mowing treatments were as follows: no mowing, same day as herbicide application, as well as 1 day, 2 days, 1week, and 2 weeks after application. Visual assessments of percent johnsongrass control were done 34 (9/17/2014), 70 (10/23/2014), and 350 (7/30/2015) days after herbicide treatment (DAT) for the 2014 trial. Assessments were done 32 (9/25/2015), 45 (10/8/2015), 53 (10/16/2015), and 298 (6/17/2016) DAT for the 2015 trial. Assessments were done 31 (9/30/2019), 60 (10/29/2019), and 376 (9/9/2020) DAT for the 2019 trial. In the 2014 trial, while Outrider had the lowest visual control (70%) without mowing 34 DAT it had the greatest control (83%) (compared to the other herbicide treatments) when mowed the same day as application. Outrider still had the greatest control (88%) when mowed the same day 70 DAT while the other herbicides ranged from 0 to 17% control. Control in the top set of treatment combinations ranged from 88 to 100% 70 DAT. Only the no mowing and 2 weeks after combinations with Acclaim Extra were in this top group. By 350 DAT control in the top set of treatment combinations ranged from 40 to 88%. Results from this trial suggest that mowing 1 or 2 days after application will not reduce the efficacy of Outrider, Fusilade, or Acclaim + Fusilade. However, one should wait 1 to 2 weeks before mowing if Acclaim Extra was applied. Regrowth of johnsongrass after mowing was slower in 2015 than in 2014 with 89% control for the Outrider and Fusilade II treatments when mowed the same day 32 DAT and 81 to 85% control 53 DAT. Control for the other herbicide treatments mowed the same day ranged from 72 to 75% 53 DAT. At the final assessment in 2016 (298 DAT) the control varied considerably among the plots and ranged from 13 to 48% for those plots that were mowed the same day in 2015, with the least control for the Acclaim Extra treatment. Regrowth was also slower and less in 2019 as there was only 0.5 cm of rainfall in the month of September. We observed 93 to 96% control with the Outrider, Fusilade II, and Acclaim + Fusilade plots that were mowed the same day 31 DAT. The Outrider and Fusilade II plots mowed the same day had 53 to 56% control 376 DAT.

2020 Survey Results for the Most Common and Troublesome Weeds in Grass Crops, Pasture and Turf. Lee Van Wychen*[1], Lavesta C. Hand[2]; [1]Weed Science Society of America, Alexandria, VA, [2]University of Georgia, Tifton, GA (34)

The 2020 Weed Survey for the U.S. and Canada surveyed the most common and troublesome weeds in the following grass crops: 1) corn (*Zea mays*); 2) rice (*Oryza sativa*); 3) sorghum (*Sorghum bicolor*); 4) spring cereal grains; 5) winter cereal grains; 5) pastures, rangeland, or other hay; and 7) turf. Common weeds refer to the weeds you most frequently see while troublesome weeds are the most difficult to control, but might not be widespread. There were 317 total survey responses from the U.S. and Canada. In corn, the top three most common weeds were 1) common lambsquarters (*Chenopodium album*); 2) *Setaria spp*.; and 3) waterhemp (*Amaranthus tuberculatus*) and the most troublesome weeds were 1) Palmer amaranth (*Amaranthus palmeri*); 2) waterhemp; and 3) *Ipomoea spp.* In rice, the top two most common and troublesome weeds were 1) *Cyperus spp.*; and 2) *Echinochloa spp*. In sorghum, the top three most common weeds were 1) Palmer amaranth; 2) *Ipomoea spp.*; and 3) johnsongrass (*Sorghum halepense*) and the most troublesome weeds were: 1) Palmer amaranth; 2) johnsongrass; and 3) *Urochloa spp*. In spring cereal grains, the top three most common weeds were 1) a tie between common lambsquarters and *Setaria spp*; and 3) wild oat (*Avena fatua*) and the most troublesome weeds were 1) *Setaria spp*.; and 2) a tie between kochia (*Bassia scoparia*) and wild oat. In winter cereal grains, the top three most common weeds were 1) *Lamium spp.*; 2) common chickweed (*Stellaria media*); and 3) *Bromus spp.* and the most troublesome weeds were: 1) Italian ryegrass (*Lolium perenne L. ssp. multiflorum*); 2) *Bromus spp*.; and 3) horseweed (*Erigeron canadensis*). In pastures, rangeland, and other hay, the top three most common weeds were 1) *Bromus spp*.; 2) Canada thistle (*Cirsium arvense*); and 3) *Ranunculus spp*. and the most troublesome weeds were 1) Canada thistle; 2) horsenettle (*Solanum carolinense*); and 3) *Bromus spp*. In turf, the top three most common weeds were 1) *Digitaria spp*.; 2) dandelion (*Taraxacum officinale*); and 3) *Poa spp.* and the most troublesome weeds were: 1) *Poa spp*., 2) *Digitaria spp.*; and 3) *Cyperus spp*. Overall, the top three most common weeds among all grass crops were 1) *Setaria spp*.; 2) *Digitaria spp*.; and 3) common lambsquarters and the most troublesome weeds were: 1) Palmer amaranth; 2) *Poa spp.;* and 3) *Bromus spp*. The 2020 weed survey data is available at: www.wssa.net/wssa/weed/surveys/.

Time to Make Dilemma-nade: Insights on the Impact of the COVID-19 Pandemic on Weed Science Extension Outreach in the USA. Nicholas J. Arneson, Rodrigo Werle*; University of Wisconsin - Madison, Madison, WI (35)

Extension outreach is vital for knowledge exchange of effective weed management and chemical herbicide use stewardship. Historically, in-person trainings, field plot tours, and on-farm visits have been key components to applied weed science outreach throughout the United States. The COVID-19 pandemic created sudden, unforeseen challenges for Extension weed scientists throughout the country as restrictions were put in place on in-person activities by state and local governments as well as academic institutions. An online survey was conducted through direct contact of weed science professionals with extension responsibilities during the Fall/Winter of 2020 to provide insight on the impact of the COVID-19 pandemic and associated restrictions on weed science Extension programming in 2020. This survey intended to reach all US states and received 49 individual responses representing weed science Extension programming in 38 states. All responses indicated at least some level of impact resulting in a shift from normal activities. Over half (55%) of represented extension programs indicated a shift to entirely virtual programming with all others adopting a hybrid approach maintaining some in-person activities. Respondents indicated increased reliance on familiar tools such as Zoom, Microsoft Teams, and Twitter to effectively maintain meaningful engagements remotely. Extension weed scientists displayed an ability to adapt and excel in these trying times through development of novel offerings of trainings and virtual tours of on-going weed science research. Nevertheless, the lack of high-speed internet and access to technology in rural areas will continue to be a barrier for effective Extension outreach dissemination. Compiling of this information allows an opportunity for the weed science community to gain insights from their colleagues' experiences in 2020 and evaluate novel strategies that are required with remote and distanced educational trainings. There is still much uncertainty on how the COVID-19 pandemic will continue to affect Extension weed science activities in 2021 and beyond. The information presented herein provides a starting point for discussion on what strategies can be effective when in-person activities are limited.

Utility of Roller Wiper Applications of Dicamba for Palmer Amaranth (*Amaranthus palmeri*) Management. Rodger B. Farr*[1], Jason K. Norsworthy[1], Thomas R. Butts[2], James W. Beesinger[1], Tristen H. Avent[1], Grant L. Priess[1]; [1]University of Arkansas, Fayetteville, AR, [2]University of Arkansas System Division of Agriculture, Lonoke, AR (36)

The commercialization of dicamba-resistant soybean (*Glycine max*) and new formulations of dicamba for use in-crop in dicamba-resistant soybean production systems has resulted in an increased concern for off-target movement of the herbicide onto sensitive vegetation. In order to mitigate the off-target movement, producers and applicators are considering utilizing application methods that do not produce spray droplets, such as rope wicks and other wiper-type applicators. While wiper-type application methods have been efficacious in a range of settings, the utility of dicamba applications using this technology has not been investigated. To determine the utility of roller wipers for dicamba applications in dicamba-resistant soybean, two studies were conducted in the summer of 2020 in Keiser and Fayetteville, AR. These studies were designed as a three-factor randomized complete block with four replications and a nontreated check. The first factor was the placement, either broadcasted, wiped at crop canopy or wiped inside of the crop canopy. The second factor was the preemergence herbicide option used: *S*-metolachlor or flumioxazin + pyroxasulfone. The third factor was the presence or absence of a second sequential application of dicamba 14 days following initial application. In Fayetteville, Palmer amaranth mortality and control were significantly influenced by interactions between preemergence and placement as well as an interaction between placement and the number of applications made. In Keiser, Palmer amaranth mortality was significantly influenced by an interaction between placement and the number of applications. Palmer amaranth control was influenced by both the number of applications, where those treatments receiving a second sequential application achieved greater control, and placement, where broadcast applications achieved the greatest amount of control followed by wiper applications made inside the crop canopy and then wiper applications made at the crop canopy. Findings from these studies show that Palmer amaranth control is sacrificed when opting to utilize wiper applications of dicamba due to the inability to manage smaller weeds that may be well below the crop canopy.

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 (37)

Palmer amaranth (*Amaranthus palmeri* S. Watson) is a difficult-to-control weed and many populations have evolved resistance to multiple herbicide sites of action (SOA). Target- and non-target-site resistance to protoporphyrinogen oxidase (PPO)-inhibitors have been identified in the Mid-South and Mid-West. Recently, a population from a long-term conservation tillage study in Kansas (KCTR) has been confirmed to be resistant to six SOAs (glyphosate, 2,4-D, ALS-, HPPD-, PSII-, and PPO-inhibitors) with predominance of metabolic-based resistance to several herbicides. Specifically, 84% of the plants survived the field recommended dose of lactofen (219 g ai ha^{-1}). Survivors were allowed to mate to produce seeds for subsequent studies. The objectives of this research were to determine the level of resistance and investigate the mechanism of resistance to the PPO-inhibitor lactofen in KCTR Palmer amaranth. A dose-response assay was performed in greenhouse to determine the level of resistance to lactofen and to assess the effect of a P450-inhibitor (malathion) on the herbicide treatment in KCTR. To determine the presence of target site mutations, the *PPO2* gene (molecular target of PPO-inhibitors) from resistant and susceptible plants was sequenced. Dose-response analysis confirmed resistance to lactofen in KCTR, and the treatment with malathion and lactofen reversed the resistance, indicating lack of metabolism *via* P450 activity. The *PPO2* sequence alignment did not reveal any previously reported or novel gene alterations known to confer resistance to PPO-inhibitors. These results confirm the involvement of P450 imparting resistance to lactofen in KCTR Palmer amaranth. Future work involves profiling of lactofen metabolites, and investigation of the genetic basis of resistance to PPO-inhibitors in KCTR.

Accumulation of Target-site Mutations in Multiple Resistant *Lolium multiflorum* Populations from Southern USA. Gulab Rangani*[1], Nilda Roma-Burgos[1], Ana C. Langaro[1], Robert C. Scott[2], Reio Salas[3]; [1]University of Arkansas, Fayetteville, AR, [2]University of Arkansas - RREC, Stuttgart, AR, [3]Dole Philippines, Inc., South Cotabato, Philippines (38)

Italian ryegrass [*Lolium perenne* ssp. *multiflorum* (Lam) Husnot] is a major weed in wheat and also carries over to rotational cotton and soybean production. A heavy infestation of ryegrass can reduce wheat yield up to 92% (Hashem *et al.*, 1998). Widespread occurrence of resistance to acetyl coenzyme A carboxylase (ACCase) and acetolactate synthase (ALS) inhibitors among Italian ryegrass populations have been reported in the US. Multiple resistance with different patterns of cross-resistance to diclofop, pinoxaden, mesosulfuron and pyroxsulam in ryegrass populations is an increasing problem. The objective of this research was to determine the resistance patterns of ryegrass populations to ACCase- and ALS-inhibiting herbicides and assess the target-site mutation profile of these populations. To achieve this objective, we sequenced the region of *ACCase* gene that codes for the catalytic domain (CT) and nearly full-length *ALS* gene in plants having diverse resistance profiles. Sequence analysis of the *ACCase* CT region showed the presence of Leu_{1781}, Asn_{2041}, Gly_{2078}, Arg_{2088} known resistance-endowing mutant alleles and some new (not documented previously) mutant alleles in some populations. The most predominant mutant allele was Asn_{2041} among populations analyzed. ALS sequence analysis is on-going. The molecular data on both target sites analyzed so far, indicated that diverse resistance is acquired through different mutant alleles in some plants, and nontarget-site mechanisms in others in the same population. Thus, the mechanisms underlying multiple resistance among *Lolium* populations involve accumulation of mutations in different herbicide targets and the presence of non-target site-based resistance in the same population or plant.

Non-target-site Resistance of Barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] to Florpyrauxifen-benzyl. Jeong-In Hwang*[1], Jason K. Norsworthy[1], Fidel Gonzalez Torralva[1], Grant L. Priess[1], Tom Barber[2], Thomas R. Butts[2]; [1]University of Arkansas, Fayetteville, AR, [2]University of Arkansas System Division of Agriculture, Lonoke, AR (39)

An arylpicolinate herbicide, florpyrauxifen-benzyl (FPB), is used to control barnyardgrass (BYG) in rice. One susceptible (Sus) and three putative FPB-resistant (R1, R2, and R3) BYG biotypes were selected based on resistance/susceptibility (R/S) ratios obtained from dose-response experiments and used to investigate the potential resistance mechanisms. Based on visual control results, the R/S ratios of BYG biotypes R1, R2, and R3 were 60-, 33-, and 16-fold greater than that of the Sus standard, respectively. Sequencing results of *TIR1* and *AFB* genes in the tested BYG showed no differences between Sus and R biotypes, meaning no presence of detectable target-site resistance. Absorption of [^{14}C]-FPB in Sus BYG increased over time and reached 90%, which was >10 percentage points greater than that in R biotypes. The [^{14}C]-FPB absorption in all R BYG equilibrated after 48 h. For both Sus and R BYG, most [^{14}C]-FPB absorbed was present in the treated leaf (79.8-88.8%), followed by untreated aboveground (9.5–18.6%) and belowground tissues (1.3-2.2%). Differences between Sus and R BYG biotypes were also found for FPB metabolism. Production of the active metabolite, florpyrauxifen-acid, was greater in Sus BYG (21.5-52.1%) than in R BYG (5.5-34.9%). In conclusion, reductions in FPB absorption and florpyrauxifen-acid production contribute to the inability to control some BYG biotypes with FPB.

Glyphosate Resistant Bird Rape Mustard (*Brassica rapa*) Through Introgression of a Transgenic Construct: Distribution and Genetic Characterization. Martin Laforest*[1], Brahim Soufiane[2], Sara Martin[3], Marie-Josee Simard[2], Katherine Bisaillon[4], Lydia Maheux[4], Sylvain Fortin[4], Tracey James[5], David Miville[6], Annie Marcoux[7]; [1]AAC-AAFC, St-jean-sur-richelieu, QC, Canada, [2]Agriculture and Agri-Food Canada, Saint-jean-sur-richelieu, QC, Canada, [3]Agriculture and Agri-Food Canada, Ottawa, ON, Canada, [4]Agriculture and Agri-Food Canada, Qc, QC, Canada, [5]Agriculture and Agri-Foods Canada, Qc, QC, Canada, [6]Minist'ere de l'Agriculture des Pecheries et de l'Alimentation du Quebec, Qc, QC, Canada, [7]Minist'ere de l'Agriculture des Pecheries et de l'Alimentation de Quebec, Qc, QC, Canada (40)

Bird rape mustard (*Brassica rapa*) is a weed reported in Canada in the province of Quebec since 1908. It is a close relative of the most widely grown species of canola, *B. napus*. Almost all of the canola grown in Quebec is transgenic (glyphosate or glufosinate resistant). Crop-weed hybrids have been observed in 2001 in locations where the crop is grown and the weed was present. In 2005, the introgression of the transgene that confers glyphosate resistance was detected in a *B. rapa* population. In 2015, unidentified mustard plants growing in a glyphosate resistant corn field located less than 130 km southeast of where introgressed plants where initially found survived a glyphosate application. These plants were identified and diagnosed as *Brassica rapa* weeds with the transgenic construct. Therefore, growers were surveyed to determine if other transgenic *B. rapa* populations were present in the area. Growers were solicited to participate in the survey via grower groups and web diffusion. Leaf sampling kits were sent to those who volunteered to participate. Twenty-eight farms sent out samples. Species specific markers confirmed that the samples were *Brassica rapa*. The transgenic construct was detected in weeds from twenty-seven farms. Moreover, one farm was not located in or close to the suspected region. Genetic analyses suggest that there were several introgression events, possibly up to six.

Phenotypic Characteristics of F_1 Hybrid Progenies Originating from Crosses Between *Sorghum bicolor* and *S. halepense*. Usha R. Pedireddi*[1], Cynthia Sias[1], Sara Ohadi[2], Nithya K. Subramanian[1], George Hodnett[1], William Rooney[1]; [1]Texas A&M University, College Station, TX, [2]University of California - Davis, Davis, CA (41)

Hybridization between crop sorghum and its weedy relative johnsongrass has significant agronomic and environmental implications. The persistence of the F_1 hybrid progenies under field environments can be governed by various morphological and reproductive traits. Experiments were conducted at the Texas A&M field research facility near College Station, TX to characterize the F_1 progeny originating from crosses between various grain sorghum parental lines and johnsongrass and in the opposite direction between johnsongrass and grain sorghum. A total of 10 morphological traits were characterized as of yet, including plant height, stem diameter, number of internodes, internodal length, number of tillers, width of the flag leaf, number of panicles/plant, length of panicle, number of rhizomatous shoots, and length of the longest rhizome. F_1 progenies derived from both maternal genetic backgrounds showed significant growth differences under field conditions. The results also indicated that there were great variation for these morphological traits among the hybrid progenies within the same parental background and ploidy type. In general, the tetraploid progenies were more robust and aggressive compared to the triploid progenies. Moreover, most of the triploid progenies did not survive the winter. The number of tillers and rhizomatous shoot production were in the increasing order of triploids, tetraploids, pentaploids, and hexaploids. On an average, the production of rhizomatous shoots was greater in the crosses with johnsongrass as the female parent compared to those with grain sorghum as the maternal parent. More research is ongoing to better understand competitive differences and persistence of different hybrid progenies.

Characterization of Johnsongrass (*Sorghum halepense*) x Grain Sorghum (*S. bicolor*) Hybridization Under Field Conditions. Nithya K. Subramanian*, George Hodnett, William Rooney, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (42)

Gene flow from cultivated sorghum to its weedy relative johnsongrass can cause ecological and environmental problems, especially if novel traits such as tolerance to abiotic and biotic stresses are transferred to johnsongrass. A field experiment was conducted at Texas A&M University, College Station during summer 2019 to understand the frequency of gene flow from grain sorghum to johnsongrass, using the acetolactate synthase (ALS)-inhibitor resistant (Inzen™) grain sorghum. Seeds harvested from johnsongrass in the Inzen™ grain sorghum fields that showed flowering synchrony with sorghum were planted in trays in the greenhouse. The seedlings were sprayed with the ALS-inhibitor nicosulfuron at three- to four-leaf seedling stage. Ploidy level of the survivors was determined using flow cytometry analysis. SNP analysis was performed to positively confirm the hybrids based on mutations specific to Inzen™ sorghum ($Val_{560}Ile$ + $Trp_{574}Leu$). Results confirmed the occurrence of gene flow from grain sorghum to johnsongrass, and all the survivors were found to be tetraploids. SNP analysis showed the presence of the $Trp_{574}Leu$ mutation (one of the two mutations present in Inzen™ sorghum) in the survivors, except for two survivors that carried both mutations ($Val_{560}Ile$ + $Trp_{574}Leu$). Screening of johnsongrass seeds harvested from Inzen™ sorghum plots during 2018 and 2020 field seasons is currently ongoing. Findings from this study offer novel insights into the outcrossing potential between johnsongrass and sorghum and are expected to help develop suitable gene flow mitigation strategies.

Future Efficacy of Preemergence Herbicides in Corn Threatened by More Variable Weather. Christopher A. Landau*[1], Aaron Hager[1], Patrick Tranel[1], Adam Davis[1], Nicolas F. Martin[2], Martin Williams[3]; [1]University of Illinois, Urbana, IL, [2]University of Illinois, Urban, IL, [3]USDA-ARS, Urbana, IL (43)

Climate change is predicted to have major impacts on US crop production. Within the US Midwest, temperatures have risen, and rainfall has become more variable. These trends are expected to continue throughout the coming century. The impact of these predicted weather changes on preemergence (PRE) herbicide efficacy has been poorly studied. The 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 individual herbicide evaluation trials spanning 252 unique weather environments, we modeled the PRE efficacy of atrazine, acetochlor, *S*-metolachlor, and mesotrione applied alone and in combinations on three common weeds species in Midwest corn production. Adequate rainfall within the first 15 days after application was essential to incorporate the herbicide into the soil and improve weed control. The probability of successful weed control with each treatment increased as rainfall increased and was maximized when rainfall was = 5–10 cm. Below this rainfall threshold, soil temperature either positively or negatively affected the probability of successful weed control depending on the herbicide and weed species. The herbicide combinations in this study required less rainfall to maximize the probability of control and had higher odds of controlling the three weed species compared to the herbicides applied individually. The more variable rainfall predicted in the coming century is likely to reduce the efficacy of common PRE herbicides in the future. However, by developing and adopting weed management strategies that utilize PRE herbicide combinations along with additional cultural, mechanical, biological, and postemergence chemical control options, some of the impacts of future weather variability can be mitigated.\

Smooth Brome (*Bromus inermis*) as a Trap for a Wheat Pest: Volatile Profiles Influence Wheat Stem Sawfly Behavior. Rekha Bhandari*[1], David Weaver[2], Tracy M. Sterling[2]; [1]Cornell University, Ithaca, NY, [2]Montana State University, Bozeman, MT (46)

Smooth brome (*Bromus inermis* Leyss.) is an important exotic perennial grass, often used for forage and for rehabilitation of disturbed land in the United States. Previous studies have claimed that smooth brome could serve as a trap crop around wheat fields impacted by wheat stem sawfly (*Cephus cinctus* Norton) (WSS), a major pest of wheat in the Northern Great Plains of North America. The use of insecticides is not effective for control of the destructive larvae that reside inside the host stem. So, trap cropping remains a potential alternative for managing WSS. However, there is a lack of knowledge on how ovipositing WSS selects hosts when encountering both wheat and smooth brome. Our objective was 1) to compare the female WSS host preference towards headspace volatiles emitted from smooth brome and wheat, 2) to evaluate their oviposition preferences, and 3) determine subsequent larval survival for these hosts at Zadoks 32 and Zadoks 49 phenological stages in the greenhouse. In a set of preliminary field observations from Montana wheat farms, we found greater WSS infestation in smooth brome stems but did not observe survival sufficient to cut mature stems in smooth brome compared to high levels of cutting in wheat. WSS preferred the headspace volatiles emitted by smooth brome over wheat in a laboratory study. There were more eggs in smooth brome relative to wheat stems, with a different proportion of infested stems in choice tests at the Zadoks 49 growth stage in cage trials. We found a greater amount of key behaviorally active compounds known to be used by female WSS, such as *(Z)*-3-hexenyl acetate and ß-ocimene. These compounds may have resulted in greater attraction of WSS females towards smooth brome, causing them to lay more eggs than in wheat. After hatch, subsequent larval mortality is greater in young smooth brome plants, resulting in stems that are seldom cut by WSS larvae at maturity. Our study provides useful information for integrated WSS management, supporting the use of smooth brome in trap cropping near wheat fields.

Potential Application of High-Intensity Red Light for Weed Seedbank Management. Albert T. Adjesiwor*[1], Andrew R. Kniss[2]; [1]University of Idaho, Kimberly, ID, [2]University of Wyoming, Laramie, WY (47)

Most agronomic weeds produce prodigious numbers of light-sensitive seeds. These seeds accumulate in the soil where they will not germinate until the soil is disturbed and they are exposed to light with a high ratio of red to far-red (high light quality). However, light sensitivity often differs among weed species. We quantified seed germination and emergence of common lambsquarters (*Chenopodium album* L.), kochia (*Bassia scoparia* (L.) A. J. Scott), redroot pigweed (*Amaranthus retroflexus* L.), barnyardgrass (*Echinochloa crus-galli* (L.) P. Beauv), Italian ryegrass (*Lolium multiflorum* (Lam.) Husnot), and wild oat (*Avena fatua* L.). Seeds were planted in potting soil and placed in the dark. The seeds were exposed daily to 8 minutes (6:00 to 6:08 pm) of either red (660 nm) or far-red (730 nm) light. An untreated check (darkness) was included for comparison. Compared to the far-red light treatment, end-of-day exposure to red light increased emergence by 14 to 52%. There was up 44% increase in emergence under the red light treatment compared to the untreated. There is a potential for field application of end-of-day red or FR light for weed seed bank management by attaching high-intensity red and FR light to wheel-line, lateral, or center-pivot irrigation systems.

Molecular Marker-based Detection and Characterization of Rice Root-knot Nematodes Infecting Weedy Rice (*Oryza sativa* Var *spontanea*) in San Juan, Batangas, Philippines.
Romnick A. Latina, Priscilla M. Barcial, Clare Hazel R. Tabernilla, Analiza Henedina M. Ramirez*; UP Los Banos, College, Los Banos, Laguna, Philippines (48)

Rice production in the Philippines has been plagued by the prevalence of weedy rice. Aside from their competitive ability that perturbs rice growth and productivity, they also serve as alternate hosts of many pests. In this study, we sought to detect and characterize the root-knot nematodes infecting weedy rice in San Juan, Batangas via molecular markers. Initial diagnosis of the infected roots displayed characteristic combination of hook and bead-like galls and female perennial pattern analysis of females from both gall types revealed akin morphology similar to those described *Meloidogyne graminicola* type specimen. DNA amplification using adult females of the nematodes based on *M. graminicola* -specific SCAR marker yielded positive detection. Moreover, ITS-rDNA-based characterization revealed 99.81% sequence similarity of the two San Juan *Meloidogyne* populations to *M. graminicola* sequences from China (Acc. No. KY660543) and India (Acc. No. MF320126) deposited in NCBI GenBank®. Phylogenetic analysis of the ITS sequences of different root-knot nematode species placed the San Juan isolates in the same clade with the other *M. graminicola* with 100% bootstrap support.
amramirez@up.edu.ph Keywords: Weedy rice, nematode, alternate host

The Effect of Row Spacing and Seeding Rate on Russian Thistle (Salsola Tragus) in Spring Barley and Spring Wheat. Judit Barroso[1], Nicholas G. Genna*[2]; [1]Oregon State University, Adams, OR, [2]Oregon State University, Pendleton, OR (49)

Russian thistle (*Salsola tragus* L.) is a persistent post-harvest issue in the Pacific Northwest (PNW). Farmers need more integrated management strategies to control it. Russian thistle emergence, mortality, plant biomass, seed production, and crop yield were evaluated in spring wheat and spring barley planted in 18- or 36-cm row spacing and seeded at 73 or 140 kg ha^{-1} in Pendleton and Moro, Oregon, during 2018 and 2019. Russian thistle emergence was lower and mortality was higher in spring barley than in spring wheat. However, little to no effect of row spacing or seeding rate was observed on Russian thistle emergence or mortality. Russian thistle seed production and plant biomass followed crop productivity; higher crop yield produced higher Russian thistle biomass and seed production and lower crop yield produced lower weed biomass and seed production. Crop yield with Russian thistle pressure was improved in 2018 with 18-cm rows or by seeding at 140 kg ha^{-1} while no effect was observed in 2019. Increasing seeding rates or planting spring crops in narrow rows may be effective at increasing yield in low rainfall years of the PNW, such as in 2018. No effect may be observed in years with higher rainfall than normal, such as in 2019.

POSTER - PHD STUDENT CONTEST

Characterize 2,4-D and Dicamba Volatility as Affected by Formulation and Exposure Duration. Patrick J. Maxwell*, Travis Gannon, Matthew C. Vann; North Carolina State University, Raleigh, NC (50)

2,4-D and dicamba are characterized by the United States Environmental Protection Agency as moderately volatile compounds. As a result, less-volatile formulations of dicamba (e.g. diglycolamine plus VaporGrip [DGA+VG]) and 2,4-D (e.g. 2,4-D choline, etc.) were introduced in combination with synthetic auxin-tolerant crop varieties. Registrants routinely use closed dome systems (i.e., humidome) with bioindicator plant species such as soybean to compare the relative volatility of newer compared to older herbicide formulations. Research was initiated to assess the suitability of utilizing tobacco (25 to 35 cm height) as a bioindicator plant species in a closed dome system to compare the relative volatility of six commercially available 2,4-D and dicamba formulations. Evaluated herbicide formulations included two 2,4-D formulations (2,4-dimethylamine [2,4-DMA], 2,4-D choline) and four dicamba formulations (DMA, DGA, DGA+VP or N,N-bis(3-aminopropyl)methylamine [BAPMA]). 2,4-D (1065 g ae ha^{-1}) and dicamba (560 g ae ha^{-1}) formulations were sprayed-applied to a course textured soil (3000 cm^3) in trays, then placed into unique humidomes along with one potted tobacco plant. Plants remained sealed in humidomes for 0 – 24, 24 – 48 or 0 – 48 hours and then removed and visually rated for injury 14 and 28 days after exposure (DAE). At 28 DAE, plant heights were measured, then plants were destructively harvested and fresh and dry mass recorded. Tobacco plants exposed to formulations containing 2,4-D (2,4-DMA, 2,4-D choline) resulted in a 2- to 4-fold increase in injury when exposed 0 – 24 h or 24 – 48 h (10 to 16%) compared to 0 – 48 h (49 to 50%). Within dicamba formulations, herbicide injury ranked: DMA (38 to 82%) > DGA (19 to 51%) = DGA + VP (15 to 43%) = BAPMA (14 to 42%) across exposure timings. Data confirms the applicability of using humidomes in combination with indicator plant species for assessing the volatility of multiple herbicide formulations simultaneously in a timely and inexpensive manner.

Supplying Phosphite as a Source of Phosphorus for Weed Suppression in *PtxD* Cotton.
Shilpa Singh*[1], Devendra Pandeya[1], Keerti Rathore[1], Kater Hake[2], Muthukumar V. Bagavathiannan[1]; [1]Texas A&M University, College Station, TX, [2]Cotton Incorporated, Raleigh-durham, NC (51)

Herbicide resistance in weeds is a major concern in the US cotton production system. Novel strategies are crucial for weed management. Phosphorus (P) is an essential macronutrient required for the normal growth and development of plants. Plants can only metabolize P in the orthophosphate (Pi) form, but unable to utilize the phosphite (Phi) form. A transgenic variety of cotton with the bacterial phosphite dehydrogenase (*ptxD*) gene has the ability to convert Phi into Pi, whereas weeds lack this ability and thus can be negatively impacted by Phi application in a P deficient soil. In 2020, a series of studies were conducted to understand the effects of Phi application on cotton (*ptxD* and non-*ptxD* varieties) and weeds [Palmer amaranth (*Amaranthus palmeri*) and johnsongrass (*Sorghum halepense*)] in three soil types: very low P [10 parts per million (ppm)], low P (15 ppm), and moderate P (25 ppm). To compare preemergence as well as postemergence effects of Phi, the experiments were conducted in a randomized complete block design with three replications. Results indicated that Phi application negatively affected weed growth, but the level of impact varied in different soil P level. Greater effect was observed in low P soil (10 to 15 ppm) on Palmer amaranth. In an experiment with glufosinate and Phi tank-mix combinations, an improvement in weed control was observed. Further investigations are required to standardize the utilization of Phi as a weed suppression tool in cotton.

Differential Expression Patterns of Three Wheat CYP81A-like Homoeologs in Response to Halauxifen-methyl and Cloquintocet-mexyl Foliar Treatments. Olivia A. Obenland*, Brendan V. Jamison, Kris N. Lambert, Dean E. Riechers; University of Illinois, Urbana, IL (52)

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* (allohexaploid bread wheat). Three *CYP81A*-like P450s located on wheat group 5 chromosomes (denoted *CYP5A*, *CYP5B*, and *CYP5D*) were previously identified by RNA-Seq analysis, which measured differential transcript expression between untreated wheat leaf tissue and leaf tissue treated with the herbicide safener, cloquintocet-mexyl (CM). Halauxifen-methyl (HM) is a synthetic auxin herbicide commonly utilized with CM in order to reduce wheat injury. We hypothesized that one or more of these group 5 *CYP81A*-like genes encode HM-detoxifying P450s that govern natural or safener-inducible tolerance to HM. The objective of this research was to utilize RT-qPCR with homoeolog-specific TaqMan primers and probes to measure expression of *CYP5A*, *CYP5B*, and *CYP5D* in wheat leaf tissue. Wheat seedlings with 1-2 leaves (Zadoks stages 11-12) were treated with CM, HM, CM+HM, or an adjuvant-only control, 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 higher than responses to HM alone. Significant inductions for all three P450 genes fluctuated over time, with significant inductions for each gene only being observed at 3 HAT. Additionally, the *CYP5D* gene consistently had higher fold inductions than its homoeologs, *CYP5A* and *CYP5B*, across all time points tested. Fluctuations over time could be due to regulation of expression by the circadian rhythm, which has been observed with other plant P450s. Overall, our results demonstrate these *CYP81A*-like genes are CM inducible but not HM inducible, suggesting a lack of additive or synergistic interactions between HM and CM. Additional functional analysis, such as gene knock-out or overexpression experiments, is necessary to test the hypotheses that the encoded P450(s) detoxify HM and that CM enhances this detoxification process.

How Are Soybean Yield Components Affected by Reduced Rates of Florpyrauxifen-benzyl? David C. Walker*[1], Eric Webster[2], Daniel O. Stephenson, IV[3], Samer Y. Rustom[1], Connor Webster[1], Bradley Greer[2], John A. Williams[1]; [1]LSU Ag Center, Baton Rouge, LA, [2]Louisiana State University, Baton Rouge, LA, [3]LSU Ag Center, Alexandria, LA (53)

Florpyrauxifen-benzyl is a new synthetic auxin that has activity on select broadleaf, grass, sedge, and aquatic weeds in rice. Like other synthetic auxin herbicides, florpyrauxifen has shown soybean to be extremely susceptible to off-target deposition injury. Therefore, a study was conducted to determine florpyrauxifen application timing and rates that can impact soybean injury and yield. The study was a RCB with a factorial arrangement of treatments. Factor A was florpyrauxifen application timings based on the soybean vegetative growth stage of V3 to V4 or reproductive growth stage of R1 to R2. Factor B was herbicide rate based on a rate titration of florpyrauxifen from the full labeled rate of florpyrauxifen at 29.44 g ai ha^{-1}. Rates of florpyrauxifen evaluated were: 7.36, 1.84, 0.46, 0.12 and 0.03 g ai ha^{-1}. Dicamba was added at 2 rates, based on previous research, that results in visual injury with a rate of 0.23 g ae ha^{-1} and a yield reduction with a rate of 7.09 g ae ha^{-1} for comparison. Herbicide applications were made using a CO_2 pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} of spray solution. Injury ratings and plant heights were recorded at 7, 14, and 28 DAT and individual yield components were quantified at harvest. Yield components evaluated included: total branch length, branch number, node number, reproductive node number, pod number, seed number and seed size. The best-fitting linear regression describing yield reduction as a function of rate applied was calculated using SAS 9.4. Results indicated that applied rates of 1.84 g ai ha^{-1} or greater of florpyrauxifen had a negative impact on all evaluated yield components. Furthermore, florpyrauxifen negatively affected more individual yield components compared with dicamba and generally to a greater degree. Rates of 1.84 g ai ha^{-1} or greater of florpyrauxifen also caused affected plants to cease pod and seed production completely while 7.09 g ae ha^{-1} of dicamba resulted in a 50 percent and 39 percent decrease in pod and seed production respectively compared to the non-treated check.

Evaluating Interaction of Dicamba, Fluthiacet-methyl, And/or Glyphosate for Control of Velvetleaf (*Abutilon theophrasti*) in Dicamba/Glyphosate-Resistant Soybean. Jose H. de Sanctis*, Amit J. Jhala; University of Nebraska - Lincoln, Lincoln, NE (55)

Velvetleaf is an economically important weed in corn and soybean production systems in Nebraska and several states in the midwestern United States. Velvetleaf has hard coated seed that can persist in soil for decades and emerge throughout the growing season when conditions are favorable. Dicamba applied alone in dicamba/glyphosate-resistant (DGR) soybean do not provide effective velvetleaf control, particularly when velvetleaf is greater than 15 cm tall. The objectives of this study were to evaluate effect of dicamba, fluthiacet-methyl, and/or glyphosate applied alone or in a mixture at variable rate combinations for velvetleaf control in DGR soybean and to evaluate if velvetleaf height (= 12 cm or = 20 cm) at the time of herbicide application may influence their efficacy and their effect on velvetleaf density, biomass, and soybean yield. Field experiments were conducted in 2019 and 2020 near Clay Center, Nebraska. The experiment was arranged in a split-plot design with four replications. The main plot treatments were velvetleaf height (= 12 cm or = 20 cm) and sub-plot treatments were a nontreated control and dicamba, glyphosate, and fluthiacet-methyl applied alone or in mixtures. Observed values were compared with expected values using a Colby's equation to determine nature of herbicide interactions. Velvetleaf control was reduced when dicamba or glyphosate was applied when plant were = 20 cm tall compared with = 12 cm tall.In general, all herbicides alone or in tank-mixtures provided satisfactory control when applied to = 12 cm tall velvetleaf plants at the higher labeled rate and control varied from 89% to 100%. When velvetleaf plants were = 20 cm tall, dicamba applied at 280 g ae ha^{-1} resulted in 49% biomass reduction at 14 days after treatment (DAT), compared with 86% biomass reduction when dicamba rate was 560 g ae ha^{-1}. Glyphosate at 1260 and 630 g ai ha^{-1} resulted in 94% and 40% velvetleaf biomass reduction, respectively. Further, application of dicamba at 280 g ae ha^{-1} plus glyphosate at 1260 and 630 g ai ha^{-1} resulted in 53% velvetleaf biomass reduction, compared with 70% estimated biomass reduction from Colby analysis, which accounts for a 17% reduction. Fluthiacet effectively controlled velvetleaf and provided 96% to 99% velvetleaf biomass reduction when applied at 4.8 and 7.2 g ai ha^{-1}, respectively.

Are Cover Crops Effective for Weed Management in the Southeast USA? A Meta-analysis.
Nicholas T. Basinger[1], David Weisberger*[1], Virginia Sykes[2]; [1]University of Georgia, Athens, GA, [2]University of Tennessee, Knoxville, TN (56)

Effects of Dicamba Vapor on Soybean Injury and Yield. Ryan D. Langemeier*[1], Steve Li[1], Greg Kruger[2], Mark L. Bernards[3], Katilyn J. Price[1], Bruno C. Vieira[4]; [1]Auburn University, Auburn, AL, [2]University of Nebraska - Lincoln, North Platte, NE, [3]Western Illinois University, Macomb, IL, [4]University of Nebraska - Lincoln, Lincoln, NE (57)

Soybean injury due to dicamba off-target movement has been widely studied, however, very few studies have addressed the effect of secondary movement (volatilization) on soybean yield. Volatilized dicamba is not associated with a salt and likely enters through the stomata which could result in different physiological effects than dicamba particle drift. The objective of this study was to evaluate the effect of dicamba vapor on soybean injury and overall yields across different growing environments. Sealed low tunnel trials were conducted Nebraska, Illinois, and Alabama in the 2020 growing season. Dicamba (Xtendimax with Vaporgrip) was applied at rates of 1/100th, 1/10th, 1X (560 g ae ha^{-1}), 10X, and 20X. Repeated applications were used to achieve 10X and 20X rates. Additionally, one treatment received 20X rate + AMS at 3.3 kg ha^{-1}. Each rate of dicamba was applied to eleven soil flats filled with green sod under each tunnel lined up parallel to soybean rows for 48 hours. Soybean was in R1 stage at dicamba exposure. Air samplers were placed on the 1X, 10X, 20X and 20X + AMS treatments at each site near the end of the 48-hour period to collect air samples. Data collection included whole plot visual injury ratings 14, 21, and 28 days after treatment (DAT) as well as pod counts, and yield were collected at the end of the growing season. Visual injury 28 DAT was not significantly different from the NTC up to a 1/10th rate. Dicamba rates of 10X and 20X resulted in 49 - 69% injury at all sites and were not significantly different 28 DAT from each other at any site. The 20X + AMS treatment resulted in 78 - 99% injury across all sites. No significant difference in yield was observed at application between 10 and 20X rates at the Alabama and Illinois sites. Combined across those sites only the 20X and 20X+AMS rate treatments resulted in significant reductions in yield. To achieve those damage levels dicamba concentrations were 888 ng m^{-3} in Alabama and 241.45 ng m^{-3} in Illinois. Dicamba volatility was able to significantly reduce yields only when extremely high levels of dicamba were present.

Residual Herbicide Use in Upland Rice Production. Connor Webster*[1], Eric Webster[2], Samer Y. Rustom[1], David C. Walker[3], Bradley Greer[2], John A. Williams[1]; [1]LSU AgCenter, Baton Rouge, LA, [2]Louisiana State University, Baton Rouge, LA, [3]Mississippi State University, Starkville, MS (58)

Upland rice (*Oryza sativa* L.), has recently gained popularity in mid-south rice production. A study was conducted in 2019 and 2020 at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana to evaluate the overlaying of residual herbicides in upland rice production. Plot size was 3-m by 9.1-m with 16-19.5 cm drill-seeded rows of hybrid long grain 'Gemini' at 39 kg ha^{-1}. The study was a randomized complete block with a two-factor factorial arrangement of treatments with three replications. Factor A consisted of early postemergence (EPOST) applications, at the one- to two-leaf rice growth stage, of 1) no EPOST application, 2) a pre-packaged mixture of imazethapyr plus quinclorac at 560 g ai ha^{-1}, 3) imazethapyr at 70 g ai ha^{-1} mixed with clomazone at 211 g ai ha^{-1}, and 4) imazethapyr at 70 g ha^{-1} mixed with pendimethalin at 1120 g ai ha^{-1}, 5) imazethapyr at 70 g ha^{-1} mixed with a pre-packaged mixture of clomazone plus pendimethalin at 717 g ai ha^{-1}, or 6) imazethapyr at 70 g ha^{-1} mixed with a pre-packaged mixture of halosulfuron plus prosulfuron at 83 g ai ha^{-1}. Factor B consisted of either no late postemergence (LPOST) application or a LPOST application at the four- to five-leaf rice growth stage of imazethapyr at 70 g ha^{-1} plus bispyribac at 34 g ai ha^{-1}. The second application of imazethapyr provided additional residual activity plus postemergence activity along with bispyribac. A uniform standard treatment of clomazone at 211 g ha^{-1} was applied preemergence. All herbicide applications were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 93.5 L ha^{-1}. Visual evaluations for the study included barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] and Texasweed [*Caperonia palustris* (L.) St. Hil.] control at 14 days after the EPOST (DAEPOST) application and 28 days after the LPOST (DALPOST) application. Rough rice yields were obtained and adjusted to 12% moisture. At 14 DAEPOST, barnyardgrass was controlled 87 to 89% when treated with a pre-packaged mixture of imazethapyr plus quinclorac. All other herbicide combinations applied EPOST controlled barnyardgrass 68 to 80% at 14 DAEPOST. At the 28 DALPOST rating date, barnyardgrass was controlled 35 to 64% when treated with any mixture applied EPOST but not followed with a LPOST application. However, barnyardgrass treated with imazethapyr plus quinclorac applied EPOST resulted in 81% control. All barnyardgrass treated with EPOST applications followed by a LPOST application of imazethapyr plus bispyribac resulted in barnyardgrass control of 85 to 94% at 28 DALPOST. Rice treated with any EPOST application followed by a LPOST application yielded 4670 to 5732 kg ha^{-1}; however, rice treated with EPOST applications of imazethapyer mixed with a pre-packaged mixture of clomazone plus pendimethalin and a pre-packaged mixture of imazethapyr plus quinclorac yielded 4746 and 4750 kg ha^{-1}, respectively. This study indicates the addition of a prepackaged mixture of imazethapyr plus quinclorac at the EPOST application timing provides an extended period of broad-spectrum residual control before an LPOST herbicide application is needed. These results suggest to overlay residual herbicides throughout the growing season in upland rice production.

Trends in Weed Control Research in Kansas Soybeans. Tyler P. Meyeres*, Terry W. Griffin, Dallas E. Peterson, Sarah L. Lancaster; Kansas State University, Manhattan, KS (59)

Integrative analysis is the analysis of multiple data sets pooled into one. Integrative analyses utilize raw data, rather than summary statistics, which are used in meta-analyses. This type of analysis is generally utilized in the medical industry, but it may prove to be useful in weed science. The objective was to analyze a multi-year data set to quantify weed control over time and effect of herbicide mode of action on Palmer amaranth (*Amaranthus palmeri* (S.) Wats) in soybeans (*Glycine max* (L.) Merr.). Trials consisted of weed control data collected five to seven weeks after planting at Kansas State University in 2015, 2016, 2017, 2018 and 2019. Trials were omitted from the data if there were missing planting dates, missing soybean traits, missing application dates, unknow herbicide active ingredient (ai), or the trial compared something other than herbicide treatments. Fifty-seven trials with 1,766 observations were included in the data set, which included 35 ai and 12 herbicide mode of action (MOA) groups. Glyphosate was the most frequently used ai and flumiclorac was the least used ai. Dicamba use increased dramatically in 2017 with the commercial release of dicamba-resistant soybeans. In general, weed control decreased for all weed species. Reduction in weed control ranged from 13% to 23% with the greatest decrease in control occurring for large crabgrass (*Digitaria sanguinalis* (L.) Scop.) and the least observed for ivyleaf morningglory (*Ipomoea hederacea* Jacq.). Palmer amaranth control by herbicide MOA also decreased over time. The greatest reduction in control was observed for herbicide mode of action groups 2, 5, and 9. From 2015 to 2019 Palmer amaranth control with herbicide mode of action groups 2, 5, and 9 decreased by 19, 23, and 20%, respectively. Reduced weed control may have been associated with an increased presence of herbicide-resistant weeds and lack of herbicide diversity. This analysis highlights the lack of ai diversity and a substantial reliance on herbicides, like dicamba and glyphosate in herbicide applications. This analysis also supports Extension recommendations that more than one herbicide MOA group should be applied, as it has been illustrated that control with certain herbicide MOA groups has declined.

Large-Scale Field Evaluation of Dicamba Volatilization When Mixed with Glyphosate.
Maria Leticia M. Zaccaro*[1], Jason K. Norsworthy[1], Grant L. Priess[1], Mason C. Castner[1], Thomas C. Mueller[2]; [1]University of Arkansas, Fayetteville, AR, [2]University of Tennessee, Knoxville, TN (60)

Sixteen field trials were conducted over two growing seasons in northwest Arkansas to quantify the relationship between dicamba air concentration and injury symptomology on soybean and assess whether environmental conditions could be associated with the concentration of dicamba detected. For every application, dicamba (XtendiMax® with VaporGrip®) at 560 g ae ha^{-1} plus glyphosate (Roundup PowerMax®) at 860 g ae ha^{-1} and drift retardant (Intact™) at 1% v/v, were applied using a tractor-mounted sprayer calibrated to deliver 140 L ha^{-1} to a 0.37 ha field with varying degrees of vegetation present. At 30 minutes after application, three high-volume air samplers collecting 185 L min^{-1} were placed in the center of the plot. Sample collection was performed for a 24, 48, 72, and 96 hour period after application (HAA) for the first year and 24 and 48 HAA during the second year. Volatile dicamba trapped in the filtering media was analyzed using LC-MS/MS at the University of Tennessee in Knoxville (TN). Greenhouse-grown dicamba-susceptible soybean (CZ 4748 LL) were placed in the field during the collection intervals and then transferred to a greenhouse for later evaluation of symptomology. Environmental conditions were monitored during and after application for the length of the collection period. The extent of soybean injury (0-100 scale) and dicamba concentration in air were regressed using the Fit Curve platform of JMP Pro 15. The best model to predict soybean injury by the concentration of dicamba in the air was a linear model of Y = a + b*(cumulative dicamba ng m^{-3} day^{-1}) with R^2 = 0.76; where a = 3.66 and b = 5.02. The relationship between reduction of soybean height (% of nontreated) and dicamba concentration was not strong (R^2 = 0.34), where a = -0.34, and b = 2.72. As expected, the amount of dicamba in the air decreased over time, but dicamba was still found from 72 to 96 HAA when a rainfall event did not occur. Strong relationships between environmental factors and dicamba detected in the air samples could not be established. Trends show that rainfall events of 2-mm or greater, reduced dicamba concentration in the air to = 1 ng m^{-3} day^{-1}.

Transplanted Industrial Hemp Tolerance to Soil-active Herbicides Grown for Cannabidiol.
Michael L. Flessner, Kevin W. Bamber, Cynthia Sias*; Virginia Tech, Blacksburg, VA (61)

The recent increase in interest from growers in the production of industrial hemp has uncovered the need for weed management options in industrial hemp. There is currently no synthetic herbicide that is labeled for use in industrial hemp production, leaving growers with limited weed control options. There is potential in currently existing chemistries to be used for weed control in hemp at the field scale. Research evaluated this hypothesis by comparing 10 different herbicides applied as a pre-plant option in transplanted hemp plots. Three separate site years were evaluated and compared in 2019 and 2020. Each location was a randomized complete block design with four replications per treatment. Data on total biomass at the plot level were collected, as well as the general phytotoxicity observed. Data were subjected to ANOVA using JMP ($P < 0.05$) and mean separation was confirmed using Fisher's Protected LSD. Treatment by site-location differences were observed as well as differences in changes in phytotoxicity over time. This information will be useful in order for regulations on chemicals to be extended for inclusion in industrial hemp production. Future ongoing research will look at the response of transplanted hemp when subjected to delayed pre- applications of these same herbicides.

Rice Weed Management Using Herbicide Coated Fertilizer. Bradley Greer*[1], Eric Webster[1], Samer Y. Rustom[2], Connor Webster[2], John A. Williams[2], David C. Walker[2]; [1]Louisiana State University, Baton Rouge, LA, [2]LSU AgCenter, Baton Rouge, LA (62)

Aquatic weed infestations can be a major problem in Louisiana rice production due to the annual rotation between rice and crawfish. Florpyrauxifen-benzyl is an important herbicide in the control of aquatic weeds; however, there have been issues with off-target movement of the herbicide. Surface-coating herbicides onto fertilizer not only eliminates an application by the grower, it also decreases the potential of off-target movement of the herbicide. A study was conducted in 2020 at the Rice Research Station near Crowley, Louisiana to evaluate foliar applications of herbicides and herbicides surface-coated onto granular urea fertilizer, 46-0-0, for control of 4 aquatic weed species. The experimental design was a randomized complete block design with a three-way factorial arrangement of treatments. Factor A was florpyrauxifen at 0, 7.3, 14.6, and 29.1 g ai ha^{-1}. Factor B was a prepackaged mixture of halosulfuorn + prosulfuron at 0, and 83 g ai ha^{-1}. Factor C was either a foliar application or a herbicide surface-coated urea application. Each 1.5 by 5.2 m plot was broken down into two components; a 1.5 by 3.6 m area that was water-seeded with 'Gemini' rice planted at a rate of 39 kg ha^{-1}, and a 0.91 m^2 galvanized metal ring area. The rings were placed in the back third of the first and third replicate and the front third of the second and fourth replicate. Aquatic weed species were collected, transplanted into rings, and clipped 14 days prior to herbicide applications to ensure active growth. All treatments including nontreated control received a fertilizer application to ensure that the herbicide treated urea did not have an advantage over the foliar treatments. Urea fertilizer was applied by hand into 6-cm flood at a rate of 168 kg ha^{-1} with weed foliage up to 40cm. Visual control ratings were taken at 14 and 42 days after treatment (DAT), fresh biomass data was collected at 42 DAT, and rice yield was collected at 85 DAT. Ducksalad (*Heteranthera limosa* (Sw.) Willd) control was 94 to 96% across all treatments evaluated at 14 DAT. At 42 DAT, the herbicide mixtures, and the florpyrauxifen on fertilizer showed 97 to 98% control of ducksalad. Ducksalad biomass was reduced 91 to 100% when compared with nontreated. Creeping water primrose (*Ludwigia peploides* (Kunth) P.H. Raven) was controlled 96 to 98% by the herbicide mixtures, but when florpyrauxifen was applied alone there was 78 to 89% control. Creeping waterprimrose was reduced 98 to 100% in the treatments containing the prepackaged mixture, whereas it was reduced 48 to 84% in the treatments containing florpyrauxifen alone. At 42 DAT, grassy arrowhead (*Sagittaria graminea* Michx.) was controlled above 88% control for all treatments except the lowest rate of florpyrauxifen applied foliarly, and the surface coated fertilizer applications of florpyrauxifen alone. For pickerelweed (*Pontederia cordata* L.); the herbicide mixtures, the foliar application of the prepackaged mixture and the florpyrauxifen at 29.1 g ai ha^{-1} on herbicide coated fertilizer gave 93 to 99% control. These treatments also reduced pickerelweed biomass 87 to 100% as compared with the nontreated. The foliar applications of florpyrauxifen and the prepackaged mixture alone controlled pickerelweed at 78 to 86%. These treatments reduced pickerelweed biomass 66 to 86% which aligned with the control ratings observed. The 7.3 and 14.6 g of florpyrauxifen surface coated fertilizer treatments only showed 36 to 39% control of pickerelweed, and a reduction of 7 to 19% as compared with the nontreated. No visual injury was observed during the growing season, but foliar applications of each treatment showed higher yields as compared to the same treatments applied on fertilizer. This is likely due to the improved weed control in the foliar treatments. While herbicide coated

fertilizer does have an application in certain situations, it is not an adequate replacement for the weed control provided with foliar application of these herbicides.

Evaluation of Cover Crops as a Sustainable Weed Management Strategy in Citrus (*Citrus sinensis*) Production. Miurel T. Brewer*[1], Ramdas Kanissery[2], Davie M. Kadyampakeni[1]; [1]University of Florida, Lake Alfred, FL, [2]University of Florida - IFAS, Immokalee, FL (63)

Citrus is part of the top five most important commodities crops in the state of Florida. Weed management represents a significant percentage of citrus production's total budget. Citrus growers face problems with many weed species in Florida due to favorable weather and production conditions. The cultivation of cover crops can benefit agricultural systems through carbon sequestration, increased soil organic matter, and weed suppression. The weed suppression comes as a result of cover crops interfering with weed germination and growth. Some cover crops can release allelochemicals, which, in the majority of the cases, can have a negative impact on the weeds reducing weed seed germination and consequently decreasing weed density. Allelochemical exudation has been identified in different plant organs such as seeds, leaves, stems, roots, and flowers; these chemicals can be exuded or leached from living and dead plant parts or released during the decomposition process. Lately, the interest in cover cropping as a sustainable weed management strategy has increased due to the effective weed suppression and other benefits like enhancement of soil quality. The current study's goal is to evaluate the effects of cover cropping as a sustainable weed management tool in suppressing weeds.The treatments included two cover crops mixes and their combination with eco-mowing (a mowing practice that places cut clippings from the row-middles into the tree rows) and no-cover crop control. The cover crop was planted in the row-middle of the orchards. The two cover crop mixes used in the study were identical except that one of the cover crop mixes did not include N-fixing species. Preliminary results indicate that cover cropping has a substantial effect on weed suppression in citrus row-middles. There was a significant reduction in weed coverage (up to 82%) in cover cropped tree row-middles compared to no cover crop control. The cover crop mix 1 (includes N-fixing legume) showed a higher reduction of weed coverage than cover crop mix 2 (without N-fixing legume) and the control. These preliminary results show the feasibility of using cover crops as a sustainable weed management strategy in citrus production.

Tolerance of Cotton Chromosomal Substitution Lines to 2,4-D: a Dose-response Study.
Willian M. Daróz Matte*[1], Loida M. Perez[2], Sukumar Saha[3], J Connor Ferguson[2], Te-Ming (Paul) Tseng[2]; [1]Maringá State University, Maringá - Paraná State, Brazil, [2]Mississippi State University, Mississippi State, MS, [3]USDA-ARS, Mississippi State, MS (64)

The development of 2,4-D-resistant crop cultivars will potentially have a significant influence on weed management. However, the off-site movement of this chemical to adjacent non-target crops and other plants is a concern in many areas worldwide, especially where sensitive non-transgenic cotton is grown. The availability of non-transgenic cultivars tolerant to 2,4-D drift will protect the yield and quality of these plants. This project uses chromosome substitution (CS) lines initially confirmed to be tolerant to field rate (1X) of 2,4-D. The objective of this research is to identify the tolerance level of selected cotton chromosomal substitution lines to 2,4-D through a dose-response study conducted in the greenhouse. The experiment was laid in a completely randomized design where six different cotton chromosomal substitution lines/varieties (CS-B15sh, CS-B16- 15, CS-B04, CS-T22sh, TM-1, and UA 48), at 2-3 leaf stage, were sprayed with five different rates of 2,4-D (0, 56, 280, 560, and 840 g ae ha-1). Plant injury and height were recorded at 14, 21, and 28 days after treatment (DAT), while shoot biomass was obtained at 28 DAT. From the regression models obtained for the dose-response curves, the necessary dose was estimated to cause 50% injury (GR50). This value was used to differentiate the different cotton lines in response to 2,4-D. The results showed that CS-B04 line presented the lowest injury values among the other CS lines, being most evident at the lowest doses of 2,4-D applied. No difference was observed among the CS lines when the herbicide rate was equal or greater than 560 g ae ha-1 for most evaluations. Plant height was mainly affected by the increase in herbicide doses, with no interaction between doses and different cotton lines. The DR50 values showed that the amount of herbicide rate necessary to cause 50% injury and/or reduction in growth and biomass variables is higher in CS-B04, followed by lines CS-B15sh and CS-B16- 15. This indicates a greater tolerance of the CS-B04 line when compared to the other lines, especially when compared to the 2,4-D susceptible lines CS-T22sh, TM-1, and UA 48. The results obtained indicate that CS-B04 cotton line can be a genetic resource for cotton breeds for developing 2,4-D drift tolerant cultivars.

Pollen-Mediated Gene Flow Between ALS-Inhibitor-Resistant and -Susceptible Johnsongrass (*Sorghum halepense*). Aniruddha Maity*, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (65)

Johnsongrass (*Sorghum halepense*) is a perennial, highly competitive, and invasive weed species that severely impacts grain sorghum, cotton, corn and other summer row crops. Herbicide resistance is a growing concern in this species, with populations resistant to the acetolactate synthase (ALS)-inhibitors, acetyl CoA carboxylase-inhibitors, and the enolpyruvylshikimate-3-phosphate synthase-inhibitor have already been reported in the United States. Pollen-mediated gene flow (PMGF) is capable of spreading herbicide resistance alleles across field populations, but the extent of this phenomenon in johnsongrass has not been well studied. Field experiments were conducted at the Texas A&M University research farm near College Station, TX in 2018 (two environments) and 2019 (one environment) to quantify the distance and frequency of PMGF from ALS-inhibitor-resistant to -susceptible johnsongrass using a Nelder-wheel field experimental design, with eight spokes (directions). The resistant biotype (pollen donor) was established at the center of the wheel (5 m diameter), and naturally occurring johnsongrass was utilized as the susceptible (pollen recipient) population, at the distance of 5, 10, 15, 20, 25, 35, 40, 45, and 50 m from the center in each of the eight directions. At flowering, the 20-25 susceptible panicles in each distance/direction that exhibited flowering synchrony with the resistant population were tagged. The tagged panicles were harvested at maturity, threshed and stored for a year under room temperature for dormancy release. Seeds were planted in controlled greenhouse conditions and sprayed with ALS-inhibitor nicosulfuron (ACCENT® Q 91.07 g a.i. ha^{-1}) at 5-6” seedling stage. The seedlings that survived after four weeks of herbicide application were counted compared to the total seedlings screened for each distance/direction and considered as the hybrids that received resistance alleles from PMGF. Greater frequency of gene flow (9.6-16.2%) was recorded at 5 m distance averaged over all the directions across the years/environments, which gradually reduced to 0.8-1.2% at 50 m distance and showed high correlation with wind direction and speed. Although the frequency of resistance alleles is low and localized at greater distances from resistance source in johnsongrass, the results indicate that ALS-resistance in johnsongrass is spreading rapidly by PMGF, which necessitates its strategic management.

Seed Production Estimation in Late-season Escapes of *Amaranthus* spp. and *Sorghum halepense* Using Drone-based Multi-spectral Imagery. Matthew Kutugata*, Chengsong Hu, Bishwa B. Sapkota, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (66)

Design of successful weed management programs is largely dependent on a sound understanding of weed ecological characteristics and population dynamics. The presence of a soil seedbank facilitates the persistence of annual weed species in arable fields. Soil weed seedbank is replenished by many sources, but the largest one is the seeds produced by uncontrolled weed escapes present during late-season. Estimation of weed seed production potential from late-season escapes may allow farmers to make appropriate management decisions and minimize seedbank replenishment. The objective of this research was to evaluate the feasibility of using UAV-based RGB and multispectral imagery for estimating seed rain potential in late-season weed escapes. Experiments were conducted at the Texas A&M field research facility in Burleson County, TX. Three case studies were used to capture images of weed escapes in agricultural fields: waterhemp (Amaranthus tuberculatus) in soybean, Palmer amaranth (Amaranthus palmeri) in cotton, and johnsongrass (Sorghum halepense) in soybean. Randomly selected quadrats with different density gradients of weed escapes were sampled at the time of crop maturity. High-resolution RGB and multispectral images of the experimental area were collected using drones, immediately prior to ground sample collection. Normalized difference vegetation index (NDVI), excess green index (ExG), and canopy height model were used for image analysis to obtain weed biological measurements (biomass and seed production). Remote sensing-based vegetation indices and plant volume estimates were effective in estimating weed seed production. Among the indices investigated, NDVI and ExG had very strong correlations (0.71 – 0.97) with weed biomass, and strong correlations (0.70 – 0.90) with seed production. Results showed that drone imagery is a powerful tool for estimating seed production from uncontrolled weed escapes and assist with management decision making. Additional experiments are required for optimizing remote sensing variables for predicting the fecundity of various weed species under field conditions.

Remote Sensing-Based Estimation of Herbicide Drift Injury and Prediction of Yield Loss in Cotton. Bishwa B. Sapkota*[1], Zachary S. Howard[1], Scott A. Nolte[2], Nithya Rajan[1], Peter A. Dotray[3], Gaylon Morgan[4], Muthukumar V. Bagavathiannan[1]; [1]Texas A&M University, College Station, TX, [2]Texas A&M AgriLife Extension, College Station, TX, [3]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX, [4]Cotton Incorporated, Cary, NC (67)

Off-target movement of herbicides onto sensitive crop cultivars has posed a serious challenge in agricultural landscapes. An ability to map and estimate herbicide drift injury, and predict their impact on crop yield using aerial images can allow for rapid and informed management decision making by growers. In this study, multispectral and thermal imagery-based approaches were implemented for evaluating injury caused by tembotrione (Laudis®) and dicamba (Xtendimax®) in cotton. DJI Matrice 600 drones mounted with a multispectral camera (Micasense RedEdge) and a thermal camera (Infrared Inc.) were used to acquire imageries. The responses were recorded at 7, 14, and 21 days after herbicide application (DAA) at two different growth stages (match-head square and early-bloom) in cotton. Deep neural networks were used for mapping and estimating herbicide injury and polynomial regression techniques were used for predicting cotton lint yield reduction. Several sets of remote sensing variables, including vegetation indices, thermal values, and canopy height model were used in prediction and mapping. Results (match-head square stage, 14 DAA) showed that herbicide injury can be mapped with fair accuracy (68% and 73% respectively for dicamba and tembotrione) using aerial imagery. Results also showed that remote sensing variables have great potential for cotton yield loss prediction (highest R^2 values of 0.85 and 0.72 for dicamba and tembotrione, respectively). The analysis for other herbicide application and observation timings are ongoing. Overall, this study demonstrates that aerial imagery can be used reliably to map herbicide injury and predict yield loss in cotton, though additional research is required to improve mapping accuracies.

Inheritance of 2,4-D Resistance in Palmer Amaranth Population from Kansas. Chandrima Shyam*, Dallas E. Peterson, Mithila Jugulam; Kansas State University, Manhattan, KS (68)

Palmer amaranth (*Amaranthus palmeri*) is one of the top-most troublesome weeds in the US, which has evolved resistance to eight herbicide modes of action (MOAs). A population of Palmer amaranth (KCTR; Kansas Conservation Tillage Resistant) was recently documented to have evolved resistance to at least six MOAs, including synthetic auxinic herbicide (SAH), 2,4-D. The objective of this research was to investigate the inheritance of 2,4-D resistance in KCTR Palmer amaranth. Four F_1 families were generated by individually crossing two parental female and male plants that were found resistant to 2,4-D with that of known 2,4-D-susceptible plants (KSS; Kansas Susceptible). Ten-12 cm tall plants from each F_1 family, along with parental plants (KCTR and KSS) were treated with 2,4-D in a dose-response fashion with the following doses i.e., 0 (non-treated), 140, 280, 560 (1X; field recommended rate), 1120, and 2240 g ae ha^{-1}. Above-ground biomass from each plant was harvested at 4 weeks after treatment (WAT), oven-dried, and weighed. Further, additional female and male F_1 plants that survived 2,4-D in the dose-response experiments were crossed to generate several pseudo-F_2 families. F_2 plants were grown and the segregation of resistance or susceptibility was assessed by evaluating their survival at 4 WAT upon treatment with 2,4-D (560 g ae ha^{-1}). F_1 dose-response analysis suggested that 2,4-D resistance in KCTR is governed by incompletely dominant nuclear allele(s). Chi-square goodness of fit analyses of F_2 segregation ratios (R:S) suggested that the 2,4-D resistance in KCTR is controlled by more than one gene. Experiments are in progress to assess response of progenies from additional F_2 families to various doses (i.e., 0.5X, 1X, and 2X) of 2,4-D. Overall, the results of this study suggest that the 2,4-D resistance in KCTR Palmer amaranth is an incompletely dominant, polygenic trait. Herbicide resistance, if governed by a single dominant allele is expected to spread faster than incompletely dominant multiple alleles. Regardless, the adoption of integrated pest management techniques can reduce selection pressure and help in managing the spread of 2,4-D resistance.

Cotton Varietal Response to Low Rates of 2,4-D. Kyle R. Russell*[1], Peter A. Dotray[2], Irish L. B. Pabuayon[1], Glen L. Ritchie[1]; [1]Texas Tech University, Lubbock, TX, [2]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX (69)

Postemergence applications of dicamba and 2,4-D to control troublesome weeds have increased since the release of auxin tolerant cotton (*Gossypium hirsutum* L.) in 2017. Off-target movement of herbicides has always been a concern; however, with the increased number of in-season applications of dicamba and 2,4-D, the risk of damaging off-target sensitive vegetation also increases. A field study was conducted at the Texas Tech New Deal Research Farm in 2020 to evaluate changes in boll distribution, yield, and fiber quality following 2,4-D exposure in four cotton varieties. Three rates of 2,4-D choline (0.00213, 0.0213, and 0.107 kg ae/ ha or 1/500X, 1/50X and 1/10X) were applied to Deltapine (DP) 1612 B2XF, DP 1822 XF, DP 1845 B2XF, and DP 1747 B2XF at first bloom using a CO_2 pressurized backpack calibrated to deliver 140 l/ha using TTI 11002 nozzles. Cotton was box mapped prior to harvest to determine boll number and distribution as affected by treatment. Second and third position bolls were grouped with first position bolls based on the similarity of bloom dates on the plant. Plots were machine harvested with a John Deere 7445 cotton stripper to determine lint yield. Biological differences in maturity were assumed between varieties, so differences are reported within variety. DP 1612 B2XF, characterized as an early maturity variety, increased boll number with all rates between nodes 5 and 10. At the 1/500X rate, boll number increased between nodes 10 and 15; however, at the 1/50X and 1/10X rates, boll number decreased. On DP 1822 XF, characterized as an early-mid maturing variety, decreases in boll number were observed between nodes 5 and 10 as well as 15 and 20 for all rates of 2,4-D. At the 1/500X and 1/50X rates, boll number increased between nodes 10 and 15, while the 1/10X rate resulted in boll loss. DP 1845 B2XF, a mid-full maturing variety, decreased boll numbers between nodes 5 and 10 following all rates of 2,4-D. At the 1/50 and 1/10X rates, boll number decreased above node 12. When 2,4-D was applied to DP 1747 B2XF, a mid-full maturing variety, boll number decreased between nodes 5 and 10 regardless of rate. While the 1/500X rate increased boll number from nodes 10 to 18, the 1/50X and 1/10X rates decreased total boll numbers in DP 1747 B2XF. Lint reductions were observed in DP 1612 B2XF and DP 1822 XF following the 1/10X rate. In DP 1845 B2XF and DP 1747 B2XF, lint reductions were observed following the 1/50X and 1/10X rates. While cotton variety relative maturity category appears to influence boll distribution changes, there interactions are not definitive. Further research is needed to better understand varietal effects.

Evaluation of Shade Cloth to Simulate Palmer Amaranth (*Amaranthus palmeri*) Competition in Sweetpotato. Levi D. Moore*, Katherine M. Jennings, David Monks, Michael D. Boyette, David L. Jordan, Ramon G. Leon; North Carolina State University, Raleigh, NC (70)

Palmer amaranth (*Amaranthus palmeri*) is the most common and troublesome weed in North Carolina sweetpotato. Previous research reported sweetpotato yield loss from Palmer amaranth was correlated with Palmer amaranth light interception. Therefore, to better understand the crop-weed interaction, field studies were conducted in 2019 and 2020 in North Carolina to compare the effects of shade cloth light interception and Palmer amaranth competition on 'Covington' sweetpotato. Treatments consisted of a seven by two factorial arrangement, where the first factor included shade cloth with an average measured light interception of 41%, 59%, 76% and 94%; Palmer amaranth thinned to 0.6 or 3.1 plants m^{-2}; or a nontreated check and the second factor included shade cloth or Palmer amaranth removal timing at 6 or 10 wk after planting (WAP). Palmer amaranth light interception peaked around 6 to 7 WAP with light interception greater than 60 and 80% for the 0.6 and 3.1 plants m^{-2} densities, respectively. F-tests comparing reduced vs full models of yield loss provided no evidence that the presence of yield loss from Palmer amaranth light interception caused yield loss different than that explained by the shade cloth at similar light interception levels. Results indicate that shade cloth structures could be used to simulate Covington sweetpotato yield loss from Palmer amaranth competition, and light interception could be used as a predictor for expected yield loss from Palmer amaranth competition.

Identification of Candidate Sex Determining Genes in *Amaranthus tuberculatus* Through Genomic Approaches. Brent P. Murphy*, Patrick Tranel; University of Illinois, Urbana, IL (71)

Waterhemp (*Amaranthus tuberculatus*) is a native, dioecious annual forb common throughout the American Midwest. While uncommon, dioecy is observed in 5-6% of angiosperm species, and is predicted to have independently evolved 81-5000 times throughout the clade. Conventionally, two components are required for dioecy: a male activator and a female repressor. One or both of these factors may be held within a region of repressed recombination, termed male-specific region (MSY), in waterhemp. The objective of this study was to identify candidate sex-determining genes within the MSY. We propose that gene models associated with one or both of the dioecy components will be unique to the MSY, and will be under purifying selection. Gene models unique to the MSY were identified from comparison to the female waterhemp genome through BLAST, where homologous gene models were defined as >80% identity across the full gene model. The ratio of nonsynonymous to synonymous variants within each gene model was calculated, and values <1 were retained as candidates under purifying selection. Utilizing both filters, the 147 gene models within contigs associated with the MSY were reduced to three candidate gene models: 00g213060, 00g213110 and 00g277460. The combination of comparative genomic and population genetic approaches is useful for the identification of candidate genes for traits of a specific character, such as dioecy.

Optimizing 2D Image Synthesis Techniques for Training Neural Network-based Weed Detection Models. Chengsong Hu*[1], Bishwa B. Sapkota[1], John Alex Thomasson[2], Muthukumar V. Bagavathiannan[1]; [1]Texas A&M University, College Station, TX, [2]Mississippi State University, Starkville, MS (72)

Precise and reliable weed mapping in agricultural fields is the key for precision weed management. Recent developments in convolutional neural networks (CNNs) have achieved significant success in weed detection and classification. CNN-based object detection, which simultaneously localizes and classifies objects in images, is one of the main artificial neural network types that have been widely used to detect crops and weeds. However, the use of CNNs in agriculture, particularly for weed management applications has been impeded by a lack of large training dataset with ground truth annotations. Image synthesis using cut-and-paste approach is one of the popular methods to alleviate the training data deficiency problem, but obtaining optimal results has not been well studied. We aim to determine the optimal cut-and-paste image synthesis approach to fill the gap between the state-of-the-art CNN performance and the limited availability of annotated images in the weed science domain, by synthesizing images using high-resolution plant segments. The image synthesis variables tested include different plant segment number, color matching methods, types of soil background and jittered image quality. Different strategies were tested using Faster-RCNN (Region-based CNN), with nine source images used for image synthesis and 500 air-borne images for testing. Good object detection results were achieved using only nine source images. The detection performance of Faster-RCNN was greatly improved with increasing number of plant segments used. The best choice of background for image synthesis was the background synthesized by a texture synthesis algorithm using soil patches from the test images. Image augmentation by quality jittering is detrimental to Faster-RCNN performance while color transformation has little influence on the performance. The results indicate that synthetic data has great potential to reduce the need for a large annotated dataset for weed detection.

Will a Drift Reducing Adjuvant Impact the Weed Control in a XtendFlex Soybean?
Jesaelen Gizotti de Moraes*, Guilherme Sousa Alves, Jeffrey A. Golus, Greg Kruger; University of Nebraska - Lincoln, North Platte, NE (73)

It is very likely that drift reducing adjuvants (DRAs) will be required for spray applications on a XtendFlex® soybean system. The objective of this study was to determine the expected control of troublesome weeds to tank-mixtures containing two or more herbicide sites-of-action as affected by DRAs. Field experiments were conducted in Nebraska during the summers of 2019 and 2020 in a randomized complete block design in XtendFlex® Soybeans. Spray treatments consisted of postemergence applications of glyphosate (1260 g ae ha^{-1}) and dicamba (560 g ae ha^{-1}) both alone and in combination and both herbicides in tank-mixture with glufosinate (656 ai $ha^{-}1$), clethodim (136 g ai ha^{-1}), clethodim plus glufosinate, clethodim plus acetochlor (1260 g ai ha^{-1}), or clethodim plus s-metolachlor (1067 g ai ha^{-1}). Tank-mixtures containing two or more herbicides were tested with two different DRAs at 0.5 % v v^{-1}. A non-treated control was included. Each treatment was sprayed with a backpack sprayer calibrated to deliver 140 L ha^{-1} at 276 kPa and at 6.4 km hr^{-1} using the TTI11002 nozzle. Experimental plots consisted of four rows (3-m wide) with 7.6 m in length replicated four times. A rectangle (77 x 32 cm) was placed in each plot allowing visual estimations of herbicide injury between-row in addition to the entire plot. At 28 d after treatment, visual estimations of injury were collected and the number of weeds inside the rectangle was counted and harvested. Data were subjected to ANOVA and means were separated using Fisher's Protected LSD test with the Tukey adjustment. Trapline Pro II increased grass control except when glufosinate was present in the tank-mixture. For Palmer amaranth, dicamba in tank-mixture with glyphosate without DRAs increased control compared to either herbicide applied alone resulting in the greatest control but not different when compared to the triple tank-mixtures (dicamba, glyphosate, and glufosinate) containing Intact, clethodim plus Intact, or clethodim plus acetochlor plus Intact. Differently from the grasses, Intact improved Palmer amaranth control when added to the tank-mixtures containing acetochlor, glufosinate, or glufosinate plus cletodim. Trapline Pro II may have enhanced grass control because of the presence of non-ionic surfactant in its composition. Results suggested that recommendations should be based on specific weed species to optimize spray application.

Seedling Emergence Patterns of *Poa annua* in Texas. Andrew W. Osburn*[1], Muthukumar V. Bagavathiannan[1], Rebecca Bowling[2]; [1]Texas A&M University, College Station, TX, [2]Texas A&M University, Dallas, TX (74)

Annual bluegrass (*Poa annua* L.) is one of the most problematic winter annual weeds in various turfgrass systems across the country, drastically driving up management costs and greatly reducing the aesthetic value of turfgrass. A sound understanding of weed seedling emergence pattern allows for appropriate timing of management interventions, yet this knowledge is limited for annual bluegrass. To evaluate annual bluegrass seedling emergence patterns, experiments are being conducted in Texas in two different USDA climatic zones (8b and 9a) over multiple growing seasons, from the fall of 2019 through the spring of 2022. For this purpose, artificial annual bluegrass seedbanks were established in eight quadrats (1 m^2) in each site in a turf field area cleared of all vegetation. Seedling emergence was evaluated on a biweekly basis throughout the year by counting and removing emerged seedlings till seedlings cease to emerge from the soil seedbank. Additionally, soil temperature and moisture were measured (5 cm depth) using weather sensors installed at the site. Between fall 2019 and spring 2020, one distinct emergence peak was observed at the zone 8b site, with 95% emergence observed within 9 weeks of first seedling emergence. Conversely, the zone 9a site had two distinct emergence peaks, with 95% emergence occurring at 19 weeks after the first seedling emergence. The preliminary results of this study indicate that environmental conditions can tremendously influence annual bluegrass seedling emergence patterns; management programs will greatly benefit from timely interventions implemented based on seedling emergence prediction.

Investigating Transcriptional Regulation of Metabolic Resistance in Palmer Amaranth (*Amaranthus palmeri*). Carlos Alberto Gonsiorkiewicz Rigon*[1], Anita Küpper[2], Roland S. Beffa[3], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Bayer AG, Frankfurt / Main, Germany, [3]Bayer AG, CropScience Division, Frankfort / Main, Germany (75)

Gene expression can be regulated by both cis- and trans-regulatory elements. The former are regulatory elements located adjacent to the target gene while the latter are located on different chromosomes or far from the target gene on the same chromosome. Transcription factors are proteins that control the rate of transcription and binds to cis-regulatory specific sequences in the promoter of a target gene. This work aims to identify important cis-regulatory specific sequences in the promoter of cytochrome P450 gene in HPPD-resistant Palmer amaranth (*Amaranthus palmeri*) population from Nebraska (NER). A previous RNAseq experiment identified *CYP81E* and *CYP72A219* as candidate genes for HPPD herbicide metabolism. qRT-PCR confirmed the high expression of both genes in parental lines at 3 and 6 h after treatment with tembotrione. Primers to amplify the promoters of both genes were designed after alignment with the available genome of Palmer amaranth. The samples used to sequence the promoter were five resistant (R) and susceptible (S) plants from an F2 population. The sequenced promoters were submitted to analysis for common or different motifs using the Multiple Expectation maximizations for Motif Elicitation (MEME-suite) tool. Gene Ontology for Motifs (GOMo) tool was used to determine if any motif was significantly associated with genes linked to one or more genome ontology (Go). The DNA length amplified upstream of *CYP81E* was 1250 bp for S and R. The promoters for the *CYP72A219* gene amplified 1380 and 1700 bp for S and R, respectively. Twelve significant binding-site motifs were found in the promoter of *CYP81E*; however, all were found in both S and R promoters. Twenty-three motifs were found in the *CYP72A219* promoter, of which three were specific to S, eight were specific to R, and 12 were shared by S and R. In the R promoter of *CYP72A219* two binding site motifs for MYB transcript factors (TF) were found. The other six motif functions were not determined using GOMo. In the S promoter, a binding site motif of Ethylene Response Factor transcription factor and ATB1 Interacting Factor were identified. Motifs for activators or repressors were not identified, despite six motifs in R promoter had not its function determined. The TF binding-sites identified were not related to a stress response. Based on these results, it appears that the high expression of *CYP81E* and *CYP72A219* in HPPD-resistant Palmer amaranth may be regulated by a trans-regulatory element.

Vegetative Growth of Palmer Amaranth (*Amaranthus palmeri*) Surviving Glufosinate Treatments in Soybeans (*Glycine max*). Eric A. Jones*, Marco Antonio Fajardo Menjivar, Diego J. Contreras, Diego E. Salazar, Charlie W. Cahoon, Ramon G. Leon, Wesley Everman; North Carolina State University, Raleigh, NC (76)

Experiments were conducted at Clayton and Rocky Mount, North Carolina to quantify the vegetative growth and female biomass of Palmer amaranth (*Amaranthus palmeri*) surviving glufosinate treatments in soybeans (*Glycine max*). Glufosinate (590 g ai ha^{-1}) was applied to 5-7 (EPOST), 7-10 (POST), and >10 cm (LPOST) Palmer amaranth. Clethodim and *S*-metolachlor were applied to control grass and later emerging weeds, respectively. Palmer amaranth (10 plants $plot^{-1}$) were allowed to grow with the soybeans for a growth comparison to the glufosinate-treated plants. Apical height and circumference were recorded weekly for six weeks. Female Palmer amaranth plants were harvested at the end of the season to determine the accumulated biomass. All main effects and interactions were significant for apical height, circumference, and female biomass ($P < 0.001$). Non-treated and glufosinate-treated Palmer amaranth plants grew larger at Clayton compared to Rocky Mount. Palmer amaranth only survived the EPOST glufosinate application at Clayton. All Palmer amaranth plants exhibited apical and circumference growth during the six week evaluation period. Despite the differential growth, female Palmer amaranth surviving glufosinate accumulated the same biomass. Results of the experiments provide evidence that Palmer amaranth surviving glufosinate treatments still exhibit growth, albeit significantly reduced compared to the in-crop Palmer amaranth plants.

Soybean (*Glycine max L.*) Exposure to Low-Rates of Dicamba. Zachary R. Treadway*[1], Todd A. Baughman[1], Robbie W. Peterson[1], Misha R. Manuchehri[2]; [1]Oklahoma State University, Ardmore, OK, [2]Oklahoma State University, Stillwater, OK (77)

Oklahoma soybean producers are facing an ever-growing problem in weed resistance to acetolactate synthase (ALS) and protoporphyrinogen oxidase inhibiting (PPO) herbicides along with glyphosate resistance. This has led to in increased reliance on newer herbicide technologies, such as the Roundup Ready 2 Xtend® soybean system. The advantage with this system is the ability for a producer to apply dicamba herbicide over the top of tolerant soybean to control troublesome weeds. The disadvantage is the potential for off-target movement of dicamba. Experiments were conducted during the 2018, 2019, and 2020 growing seasons at the Oklahoma State University Mingo Valley Research Station near Bixby, Oklahoma to simulate the effects of single and multiple exposures of dicamba on non-dicamba tolerant soybean. Liberty-Link soybean (*Glycine max* L.) were planted on May 22, 2018, June 13, 2019, and June 1, 2020. Plots were four 76-cm rows by 7.6 m long and included four replications. The center two rows were sprayed with dicamba at 0.056 g ae ha^{-1} (1/10,000X labeled rate) or 0.56 g ae ha^{-1} (1/1,000X labeled rate). Individual treatments were applied at the V2 growth stage or the R1 growth stage. Treatments were either applied once or followed with two additional applications 7-14 and 21-28 days after initial treatment. A V2 followed by R1 application was also included. Plots were maintained weed free throughout the growing season. Visual soybean injury occurred with all dicamba treatments, however varied by treatment and timing. Visual injury 2 WAT never exceeded 10% when dicamba was applied at 0.056 g ae ha^{-1}. When dicamba was applied at 0.56 g ae ha^{-1}, visual soybean injury 2 WAT did not exceed 10% in 2018, with the exception of 3 applications beginning at V2 (24%) and 3 applications beginning at R1 (18%). Visual injury exceeded 15% with all applications except the V2 alone in 2019 (5%) and 2020 (13%). Visual injury 2 WAT exceeded 20% all three years with the V2 followed by 2 additional POST treatments. This was also true for the R1 followed by 2 additional POST treatments in 2019 and 2020. Soybean yields were not affected by any treatment in 2018 regardless of application timing or rate. This was true even in the instances where visual soybean injury exceeded 20%. Yields were lower in all cases when multiple soybean exposure to dicamba occurred in both 2019 and 2020. The differences in 2018 compared to 2019 and 2020 may be due to the earlier planting and environmental conditions allowing for soybean to recover from injury that year. Yields were never affected by a single exposure of dicamba at V2 and only in 2020 from a single exposure at R1. Data from these experiments shows that plant injury does not always equate to yield loss. However, care should always be taken when applying dicamba around susceptible soybean since visual plant damage and yield reductions can occur from off-target movement.

Using Recombinant Inbred Lines of Sorghum for Studying Genetic Control of Inter-specific Hybridization Between *Sorghum bicolor* and *S. halepense*. Usha R. Pedireddi*, Nithya K. Subramanian, George Hodnett, Patricia Klein, William Rooney, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (79)

Recombinant Inbred Lines (RILs) serve as powerful tools for genetic mapping of traits of interest. An experiment is being conducted at Texas A&M University, College Station, to understand chromosomal regions that influence outcrossing potential between sorghum (*Sorghum bicolor*) and johnsongrass (*S. halepense*). In this study, RIL lines developed from crosses between sorghum inbreds with high (Tx623) and low (Tx378) outcrossing potential with johnsongrass were investigated. A total of 192 RIL lines were planted in a field naturally infested with johnsongrass, in a completely randomized design with three replications. Sorghum was the female parent, and to prevent self-pollination the male gametocide agent trifluoromethanesulfonamide (TFMSA) was applied to foliar tissue at 3 to 10 days prior to flag leaf emergence. At seed maturity, 15 panicles were harvested individually within each plot. Preliminary results showed substantial variation in seed set among the RIL lines evaluated. To understand the chromosomal locations affecting gametic factors in sorghum, a genotyping by sequencing (GBS) analysis will be conducted and the genetic data will be compared with the phenotypic data. Results are expected to provide novel insights on the genetic control of outcrossing between sorghum and johnsongrass.

Developmental Factors Influencing Resistance to PPO Inhibitors. Abigail Barker*, Franck E. Dayan; Colorado State University, Fort Collins, CO (80)

Since the evolution of resistance to PPO-inhibiting herbicides there have been multiple observations that plants resistant to post-emergent applications of PPO inhibitors are still controlled by pre-emergent treatments, although in a pre-emergent dose response they still show a similar LD50 ratio to the post-emergent dose response. Resistance to PPO-inhibiting herbicides is further complicated by the presence of two isoforms of the PPO protein in plants, namely PPO1 implicated in chlorophyll synthesis and PPO2 implicated in heme synthesis. In the past the accepted paradigm was that inhibition of PPO1 was more important since there is more metabolic flux through that pathway in plants, but most resistance mutations are on the PPO2 protein. Transcript levels of the two isoforms in waterhemp do not explain the higher susceptibility of younger plants. The interaction of the MOA of glufosinate with PPO inhibitors suggests glutamate could be a factor in the efficacy of PPO inhibitors, though when measured through LC-MS results show lower glutamate levels in younger plants. Plants supplemented with glutamate show slightly increased damage upon PPO inhibitor treatment. Antioxidants have a protective effect against PPO-inhibiting herbicides. Younger plants show lower antioxidant capacity than older plants, which could be a contributing factor. Other factors that can change over development include herbicide absorption and amount of herbicide per gram of tissue from the treatment. Results have bearing on future best practices to avoid loss of pre-emergent PPO activity.

Can Significant Amounts of Glyphosate and Glufosinate Transfer to Almonds During Harvest Operations? Katie Martin*[1], Brad Hanson[2]; [1]University of California - Davis, Davis, CA, [2]University of California - Davis, Winters, CA (81)

California almonds are a $6 billion industry and a majority of the commodity is exported. The European Union (EU) is the main recipient of exported almonds; a 2019 study completed by the European Food Safety Authority recommended the EU maximum residue limit (MRL) for glyphosate be reduced from 0.1 mg/kg to 0.05 mg/kg. Almonds are harvested from the orchard floor; prior to harvest it is common practice to control the orchard floor vegetation using broadspectrum herbicides. US labels set the minimum pre-harvest intervals (PHIs) for two commonly used herbicides, glyphosate and glufosinate, at 3 and 14 days, respectively. The aim of this project was to determine if herbicide transfer from soil to almonds during harvest process could contribute to low levels of residue in the commodity and whether lengthening the PHI would result in lower residues. A field experiment set up as a RCBD with four replications contained plots that were treated with a tank mix of glyphosate (1658 g ae ha^{-1}) and glufosinate (1680 g ae ha^{-1}) mixed with 0.25% v/v NIS and 1% v/v AMS applied 35, 21, 14, 7, or 3 days prior to almond harvest. Almonds were shaken from the trees by hand and then swept into windrows using commercial equipment. Samples of almonds were collected from each plot, dissected into hulls, shells, and kernels, and analyzed for glyphosate, glufosinate, and their metabolites using LC-MS/MS. A separate laboratory experiment was conducted using radiolabeled glyphosate and glufosinate to evaluate herbicide transfer via dust to harvested almonds. Dry field soil was sieved and treated with 1.665 MBq of ^{14}C herbicide and almonds were tumbled in this herbicide-treated dust. Hull, shell, and kernel fractions of the almonds were analyzed separately for ^{14}C herbicide residues using a biological oxidizer and a liquid scintillation counter. The results of these experiments indicate that very low levels of herbicide transfer to almond shells and kernels and that the residues are primarily bound to soil particles on those fractions. Glyphosate and its metabolites were not detected in almond kernels while glufosinate and metabolites were detected below the current MRL but above the new proposed MRL. Increasing the PHI from their current label requirement did not significantly reduce the already low amount of herbicide or metabolites in almond.

Biochemical Characterization of Acetyl-CoA Carboxylase with an Ala2004Val Mutation That Confers Quizalofop Resistance in CoAXium® Wheat. Raven Bough*, Franck E. Dayan, Todd A. Gaines; Colorado State University, Fort Collins, CO (82)

The quizalofop tolerance trait in CoAXium wheat is primarily conferred by a mutation at position 2004 in two of three acetyl-CoA carboxylase (ACC1) homoeologs that results in an alanine to valine amino acid substitution. The substitution likely causes a conformational change in acetyl-CoA carboxylase (ACCase) that provides resistance to the inhibitor quizalofop.To determine if the mutation affects ACCase specific activity, quizalofop-susceptible and -tolerant ACCase was extracted from wheat. Tissue was collected from three susceptible cultivars and nine resistant cultivars or lines and flash frozen prior to extraction. Frozen tissue was first homogenized to release ACCase into solution. After filtering excess plant tissue from the solution, ACCase was precipitated using a combination of ammonium sulfate saturation and centrifugation. Enzyme pellets were reconstituted in elution buffer and desalted with Sephadex columns. Extracts were immediately incubated in a buffered solution containing ATP and ^{14}C-labeled bicarbonate substrate. The limiting substrate, acetyl-CoA, was added to initiate the formation of the ACCase product, malonyl-CoA. After 10 minutes, the reaction was quenched using 12 M hydrochloric acid. Unincorporated ^{14}C-labeled bicarbonate was released as gaseous carbon dioxide, whereas ^{14}C used by ACCase to form malonyl-CoA remained in the assay solution. After drying overnight, assay residue was mixed with scintillation cocktail and specific activity was quantified using a liquid scintillation analyzer. A one-way ANOVA indicated that there were no significant differences (a=0.05, n=3) in specific activity between susceptible and resistant ACCase extracts.

The Effects of Inter-seeded Winter Wheat on Weed Suppression and Soybean Yield.
Madison R. Decker*, Ronald F. Krausz, Karla L. Gage; Southern Illinois University Carbondale, Carbondale, IL (83)

There is an urgent need to progress towards more sustainable weed management practices that increase crop productivity while slowing the evolution of herbicide resistance. Cover crops and inter-seeded crops may diversify the evolutionary selection pressures on weeds and provide an additional tool for integrated weed management. 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 concurrent with soybean and the inter-seeded winter wheat was terminated at various soybean growth stages from soybean 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 where winter wheat was 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 inter-seeded winter wheat was terminated when compared to the standard soybean-only PRE fb POST program. In the planting date study, at both locations, 0 days after the POST, common waterhemp biomass was significantly reduced when compared to the soybean-only non-treated treatment when winter wheat was planted prior to soybean in the fall, April, or early May planting dates. Yield from the ARC planting date study indicated that planting winter wheat 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.

POSTER - MS STUDENT CONTEST

Investigation of Management Strategies to Optimize Cover Crop-Based Weed Mitigation in Canadian Sweet Corn Production. Hayley Brackenridge*[1], Jichul Bae[2], Marie-Josee Simard[3], Francois Tardif[1], Kerry Bosveld[4], Robert E. Nurse[4]; [1]University of Guelph, Guelph, ON, Canada, [2]Agriculture and Agri-Food Canada, Agassiz, BC, Canada, [3]Agriculture and Agri-Food Canada, Saint-jean-sur-richelieu, QC, Canada, [4]Agriculture and Agri-Food Canada, Harrow, ON, Canada (84)

Fall sown cereal rye (*Secale cereal* L.) has gained popularity as a cover crop due to its weed-suppressive capabilities. When mechanically terminated with a roller-crimper, this method of weed control makes an inexpensive enhancement to an integrative weed management program. Research has shown that early milk, occurring in mid-June, is the optimal stage for cereal rye termination via roller-crimper. However, roller-crimping at this timing would cause significant delays in cash crop planting, potentially compromising yields. Therefore, the objective of this research was to identify an earlier maturing cereal rye cultivar. Two cereal rye cultivars (early vs. standard maturity) were compared at three seeding rates (150, 300, and 600 seeds m^{-2}) for their effect on rye biomass and weed control. The trial was conducted at Agassiz, BC, Harrow, ON, and St. Jean-sur-Richelieu, QC in 2019 and at Harrow and St. Jean-sur-Richelieu in 2020. Results thus far suggest that the early maturing cereal rye cultivar reaches early milk two to seven days earlier than the standard cultivar at Agassiz and Harrow. This suggests that earlier roller-crimping may be possible at these locations. Additionally, rye biomass was weakly correlated to weed control 56 days after crimping, however, the strength of this relationship varied among locations and years. In Harrow and St. Jean-sur-Richelieu, both cultivars controlled weeds better when sown at 600 seeds m^{-2} than 150 seeds m^{-2}. These findings emphasize the complexity of roller-crimping cereal rye for weed mitigation and the importance of multi-site-year studies to draw regionally specific conclusions.

Crop Response and Weed Management Systems Utilizing Isoxaflutole in HPPD Tolerant Cotton. Delaney C. Foster*[1], Peter A. Dotray[2], Corey Thompson[3], Greg Baldwin[4], Frederick T. Moore[5]; [1]Texas Tech University, Lubbock, TX, [2]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX, [3]BASF, Abernathy, TX, [4]BASF, Research Triangle Park, NC, [5]BASF, Lubbock, TX (85)

Over half of the nation's cotton is planted in Texas with 1.6 million hectares residing in the Texas High Plains. Since 2011, glyphosate resistant Palmer amaranth (Amaranthus palmeri S. Watson) has challenged cotton production and alternatives to glyphosate are needed. Integrating soil residual herbicides into a weed management program is an important step to control glyphosate resistant weeds before they emerge. BASF Corporation is developing p-hydroxyphenylpyruvate dioxygenase (HPPD) tolerant cotton, which will allow growers to use isoxaflutole, an HPPD inhibiting WSSA Group 27 herbicide, in future weed management programs. In 2019 and 2020, field experiments were conducted at New Deal, Lubbock, and Halfway, Texas to evaluate HPPD-tolerant cotton response to isoxaflutole applied preemergence (PRE) or early-postemergence (EPOST) as well as to determine the efficacy of isoxaflutole when used as part of a weed management program. Crop response experiments at New Deal and Lubbock included the following treatments: prometryn at 1.35 kg ai/ha PRE followed by (fb) glufosinate at 0.88 kg ai/ha + S-metolachlor at 1.4 kg ai/ha EPOST, isoxaflutole at 0.11 kg ai/ha + prometryn PRE fb dimethenamid at 0.84 kg ai/ha + glufosinate EPOST, isoxaflutole + pendimethalin at 1.12 kg ai/ha PRE fb dimethenamid + glufosinate EPOST, isoxaflutole + prometryn + pendimethalin PRE fb dimethenamid + glufosinate EPOST, isoxaflutole + prometryn at 0.67 kg ai/ha (″ rate) PRE fb glufosinate + S-metolachlor EPOST, isoxaflutole + prometryn PRE fb glufosinate + S-metolachlor EPOST, isoxaflutole + fluometuron at 1.12 kg ai/ha PRE fb glufosinate + S-metolachlor EPOST, prometryn PRE fb isoxaflutole + glufosinate EPOST, and prometryn PRE fb isoxaflutole + glufosinate + glyphosate at 2.1 kg ai/ha EPOST. A blanket mid-postemergence (MPOST) application of glyphosate at 2.1 kg ai/ha + glufosinate at 0.88 kg ai/ha was made at first bloom and some treatments received diuron at 1.12 kg ai/ha postemergence-directed (PDIR) when cotton was at the bloom stage. At New Deal, cotton response was greatest following the EPOST application, but did not exceed 10%. Cotton response was greatest following the PRE application at Lubbock in 2019, but never exceeded 14%. In 2020 at Lubbock, cotton was replanted due to a damaging wind event. There was <1% cotton response following the PRE application and maximum cotton response observed was 9% following EPOST and MPOST applications. By late season, no cotton response was detectable. There was no difference in cotton stand at either location. Cotton lint yield ranged from 1,214-1,425 kg/ha at New Deal and 675-758 and 1,544-1,729 kg/ha in Lubbock in 2019 and 2020, respectively. Lint yields were not different from the nontreated weed-free control. In non-crop weed control studies at Halfway, treatments mimicked the cotton response trials, but also included isoxaflutole + prometryn PRE fb glyphosate + dicamba at 0.56 kg ai/ha EPOST and prometryn PRE fb isoxaflutole + glyphosate + dicamba EPOST. These two treatments included glyphosate + dicamba MPOST. All PRE treatments containing isoxaflutole controlled Palmer amaranth =94% 14 and 21 days after treatment. All treatments controlled Palmer amaranth =94% 21 days after the EPOST application. Twenty-one days after the MPOST treatment, systems with isoxaflutole EPOST controlled Palmer amaranth 88-93% while systems with isoxaflutole PRE controlled Palmer amaranth 94-98%. End of season Palmer amaranth control was lowest in the system without isoxaflutole (88%) and when isoxaflutole was used EPOST (88-91%). These studies suggest that the opportunity to use isoxaflutole in cotton weed management systems will improve season-long control of several troublesome weeds with no adverse effects on cotton yield and quality.

Assessing St. Augustinegrass (*Stenotaphrum secundatum*) Grow-in Following Preemergence Herbicide Application. Amy L. Wilber*[1], James D. McCurdy[2], Joby Czarnecki[1], Barry Stewart[1], Hongxu Dong[1]; [1]Mississippi State University, Mississippi State, MS, [2]Mississippi State University, Starkville, MS (86)

St. Augustinegrass (*Stenotaphrum secundatum*) is a commonly produced lawn grass in the southeastern and gulf-coastal United States. Producers routinely apply preemergence herbicides to prevent annual weed infestation in turfgrass production fields. Preemergence herbicides may negatively affect grow-in of the desired turfgrass species. Our objective was to assess St. Augustinegrass grow-in following application of commonly used preemergence herbicides. Field research was conducted at Mississippi State University as a randomized complete block design with four replications replicated twice in time (2019 and 2020). Ten plugs (232 cm^2 apiece) of MS-B-2-3-98 St. Augustinegrass were planted within each experimental unit (2.32 m^2) on 12 June 2019 and 14 May 2020. One day after planting, preemergence herbicide treatments were applied using a CO_2 pressurized back-pack sprayer in a water carrier volume of 374 L ha^{-1}. Treatments included a nontreated check, prodiamine (0.595 kg ai ha^{-1}), pendimethalin (1.66 kg ha^{-1}), oxadiazon (2.24 kg ha^{-1}), *S*-metolachlor (2.78 kg ha^{-1}), atrazine (2.24 kg ha^{-1}), atrazine + *S*-metolachlor (2.24 + 1.74 kg ha^{-1}), and dithiopyr (0.42 kg ha^{-1}), as well as the treated-check, indaziflam (0.0327 kg ha^{-1}). Irrigation was applied four hours after treatment. Percentage St. Augustinegrass cover was assessed weekly. Data were regressed using a sigmoidal, variable slope curve to estimate days to reach 50% cover ($Days_{50}$) with 95% confidence intervals within GraphPad Prism 9. Extra sum-of-squares F-tests were conducted using GraphPad Prism 9 to compare the fit of regression curves. In 2019, prodiamine (107d to reach 50% cover;), pendimethalin (94d), oxadiazon G (88d), *S*-metolachlor (89d), atrazine + *S*-metolachlor (90d), dithiopyr (93d), and indaziflam (357d) increased $Days_{50}$ compared to the nontreated (84d). In 2020, prodiamine (61d), *S*-metolachlor (65d), dithiopyr (59d), and indaziflam (96d) increased $Days_{50}$ compared to the nontreated (55d). Prodiamine, *S*-metolachlor, dithiopyr, and indaziflam treatments increased days to reach 50% cover in both 2019 and 2020. In 2019, regression curves of oxadiazon WSP and atrazine were similar to the curve of the nontreated. In 2020, regression curves of pendimethalin, oxadiazon WSP, atrazine, and atrazine + *S*-metolachlor were similar to the curve of the nontreated. Producers must consider their target weeds along with the impact on sod grow-in when making preemergence herbicide applications. Based on 2019 and 2020 results, atrazine or oxadiazon WSP can be recommended (at rates applied in this study) for preemergence weed control in St. Augustinegrass without affecting time to grow-in. Despite prodiamine, *S*-metolachlor, and dithiopyr delaying cover in both years, future research may better determine whether benefits of weed control outweigh delayed cover.

Crabgrass (*Digitaria sanguinalis*) *C*Ontrol by Tank Mixes and Carrier Volumes Used in 2,4-D Resistant Soybeans. Chad J. Lammers*, Sarah Lancaster, Tyler P. Meyeres; Kansas State University, Manhattan, KS (87)

Herbicide co-application increases farm efficiency and facilitates control of a broader spectrum of weed species. However, herbicide application requirements may conflict and antagonism may occur. Enlist E3 resistant soybean varieties allow farmers to apply combinations of 2,4-D choline, glyphosate, and glufosinate. Antagonism has been documented with these tank mixes, specifically when applied to large crabgrass (*Digitaria sanguinalis* L.) A greenhouse experiment was conducted to determine large crabgrass control by tank mixes applied with carrier volumes of 93-, 140-, and 187- L ha^{-1} on 5-, 10-, and 20- cm large crabgrass. Tank mixes contained 2,4-D + glyphosate, 2,4-D + glufosinate, glufosinate + glyphosate, and 2,4-D + glufosinate + glyphosate and each tank mix included ammonium sulfate. A non-treated check was included for each plant height. Experiments were conducted in the Kansas State University Weed Science greenhouse in 10-cm square pots containing 1 crabgrass plant. Plants were sprayed with a track sprayer and randomized in a split-split plot design according to replication and plant height at application. Plants were grown for 4 weeks with visual ratings recorded at 1-, 2-, and 4- weeks after treatment (WAT). At 4 WAT above ground biomass was harvested. Wet and dry weights were recorded. Data were subjected to analysis of variance (and means separation (Tukey's pairwise comparisons, a = 0.05) using the packages lmer, anova, and emmean in R. Control from all treatments ranged from 47- to 100%. Weed control was similar for all carrier volumes, regardless of large crabgrass height. Treatments with 2,4-D + glyphosate, regardless of carrier volume and weed height at application, had approximately 100% control. Tank mixes containing glufosinate at the 10- and 20-cm sizes had between 52- and 65% or 47- and 78% control, respectively. In conclusion, control of large crabgrass was less when applied in combinations that included glufosinate or glufosinate plus 2,4-D than in when applied with 2,4-D alone when applied to 10- and 20-cm large crabgrass, regardless of carrier volume.

Interaction of Trifludimoxazin + Saflufenacil and Pyroxasulfone for Control of False Cleavers (*Galium spurium*). Kathryn Aldridge*, Eric N. Johnson, Steve J. Shirtliffe; University of Saskatchewan, Saskatoon, SK, Canada (88)

The development of herbicide resistant (HR) weeds has led to a need for examining alternative herbicide mechanisms of action for weed control. The objectives of this study were to examine the herbicide interaction of trifludimoxazin + saflufenacil (Group 14) and pyroxasulfone (Group 15) on residual weed control in wheat, and to determine the type of herbicide interaction present: additive, synergistic, or no effect. This study was conducted at four different locations during the 2020 growing season. Wild oat and false cleavers were cross-seeded in 2 m strips across the experimental area in a split-block design. Treatments comprising of two factors (herbicide group and rate) were applied perpendicular to the weed strips in a randomized complete block design (RCBD) with four replicates. The treatments for this study consisted of four different rates (1, 1.5, 2.0, and 2.5X) of BAS85100H (2:1 pre-mix of saflufenacil and trifludimoxazin (18, 27, 36, 45 g ai h^{-1}) and pyroxasulfone (60, 90, 120, 150 g ai ha^{-1}) applied alone and as a tank-mix. Additional treatments included an untreated check and commercial checks of two rates of Heat Complete® (saflufenacil (18, 36 g ai h^{-1}) and pyroxasulfone (60, 120 g ai h^{-1})). Crop phytotoxicity and herbicide efficacy ratings were taken 7-14, 21-28, and 36-40 days after emergence (DAE). Both herbicide group and rate were shown to be significant at $p = 0.05$ for each weed species. Flint's adaptations to Colby's equation was used to determine the relationship present between the herbicide groups. The Group 14+15 tank-mix displayed the highest level of false cleavers control, with 92% control being the highest efficacy being observed. The Group 14+15 tank-mix performed significantly better than that of Group 14 and 15 alone. A comparison of the actual versus expected weed control showed that false cleavers control obtained with the tank-mixes was almost identical to the expected, indicating an additive relationship. Utilizing a mixture of Group 14+15 herbicides improves weed control compared to the individual groups, thereby improving HR weed management of false cleavers.

Efficacy and Crop Safety of Dimethenamid-P, S-Metolachlor, and Pyroxasulfone for Management of ALS-Inhibitor-Resistant Palmer Amaranth (*Amaranthus palmeri*) in Dry Edible Bean. Joshua Wa Miranda Teo*[1], Jeff Bradshaw[1], Amit J. Jhala[2], Nevin Lawrence[3]; [1]University of Nebraska - Lincoln, Scottsbluff, NE, [2]University of Nebraska - Lincoln, Lincoln, NE, [3]University of Nebraska, Scottsbluff, NE (89)

Dimethenamid-P is currently the only Group 15 herbicide registered for use POST in dry edible bean. Dimethenamid-P can provide season-long ALS-inhibitor-resistant Palmer amaranth control in dry edible beans when used in a sequential PRE/POST program. S-metolachlor is registered only for PRE applications, while pyroxasulfone is not registered for use in dry edible beans. A field study was conducted in Scottsbluff, NE to compare S-metolachlor and pyroxasulfone with dimethenamid-P in a PRE-only and sequential PRE/POST program for potential use in dry edible bean. Treatments included a non-treated check; dimethenamid-P (685 g ai ha^{-1}) PRE; S-metolachlor (1,070 g ai ha^{-1}) PRE; pyroxasulfone (150 g ai ha^{-1}) PRE; dimethenamid-P (580 g ai ha^{-1}) PRE followed by (fb) dimethenamid-P (475 g ai ha^{-1}) at V1; S-metolachlor (1,070 g ai ha^{-1}) PRE fb S-metolachlor (800 g ai ha^{-1}) at V1; pyroxasulfone (150 g ai ha^{-1}) PRE fb pyroxasulfone (150 g ai ha^{-1}) at V1; and dimethenamid-P PRE fb fomesafen plus imazamox plus basagran at V1, as a weed-free control. All PRE applications contained a tank-mix with pendimethalin (1,070 g ai ha^{-1}). S-metolachlor and dimethenamid-P applied sequentially PRE/POST provided similar Palmer amaranth control as fomesafen plus imazamox plus basagran applied POST. Pyroxasulfone provided effective Palmer amaranth control when applied PRE-only and sequentially PRE/POST. Pyroxasulfone applied PRE caused 52% injury 0 d after POST application and applied sequentially PRE/POST caused 58% and 47% injury 0 and 14 d after POST application, respectively. Dimethenamid-P and S-metolachlor provided excellent crop safety. E-mail: jmirandateo2@huskers.unl.edu

Activity Interactions of a Gambit Plus Propanil Mixture in Rice Production. John A. Williams*[1], Eric Webster[2], Bradley Greer[2], David C. Walker[1], Connor Webster[1], Samer Y. Rustom[1]; [1]LSU AgCenter, Baton Rouge, LA, [2]Louisiana State University, Baton Rouge, LA (90)

Producers often mix multiple herbicides to help broaden weed control spectrum and save money. Often these herbicides are not compatible for some reason and control decreases compared with the products applied alone. Producers in Louisiana have mentioned a reduction in the control of alligatorweed [*Alternanthera philoxeroides* (Mart.) Griseb.] and other broadleaf weeds when treated with a co-application of a pre-packaged mixture of 50% halosulfuron and 29% prosulfuron, sold under the tradename Gambit®, plus propanil. A study was conducted at the H. Rouse Caffey Rice Research Station near Crowley, Louisiana to evaluate the interaction between three rates of Gambit and two formulations of propanil. Plot size was 3-m by 9.1-m with 16-19.5 cm drill-seeded rows of long grain imidazolinone-resistant 'CL-111' rice at 78 kg ha^{-1}. The study had a randomized complete block design with a two-factor factorial arrangement of treatments with three replications. Factor A consisted of an application of Gambit at 0, 27.7, 55.4, or 82.9 g ai ha^{-1}. Factor B consisted of two different propanil formulations, an EC and SC, applied at 0 or 3360 g ai ha^{-1}. Gambit and propanil were applied at the three- to four-leaf stage of rice, or mid-postemergence (MPOST). A 1% v v^{-1} crop oil concentrate (COC) was added to any spray solution containing the SC formulation of propanil or Gambit applied alone. No COC is required with the EC formulation. A uniform standard treatment of clomazone at 336 g ai ha^{-1} was applied preemergence (PRE) for grass control. All herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 93.4 L ha^{-1}. Visual evaluations for this study included alligatorweed and hemp sesbania [*Sesbania herbacea* (Mill.) McVaugh] at 14 and 28 days after treatment (DAT). At 14 DAT, control of alligatorweed treated with Gambit at 22.7 g ha^{-1} applied alone was 60%. However, when 22.7 g ha^{-1} of Gambit was mixed with either formulation of propanil at 3360 g ha^{-1}, control decreased to less than 20%. Alligatorweed treated with Gambit applied at 55.4 g ha^{-1} alone resulted in 70% control; however, the addition of either formulation of propanil at 3360 g ha^{-1} to that rate of Gambit decreased alligatorweed control to 33 to 47%. At 28 DAT, alligatorweed treated with 22.7 g ha^{-1} of Gambit alone was controlled 60%, but with the addition of the EC or SC formulation of propanil, alligatorweed control was decreased to 30 and 23%, respectively. Increasing the rate of Gambit to 55.4 g ha^{-1} alone controlled alligatorweed 80%; however, alligatorweed control dropped significantly when Gambit at 55.4 g ha^{-1} was mixed with either formulation of propanil to 43% control. At both 14 and 28 DAT, no visual reduction in control was observed when 82.9 g ha^{-1} of Gambit was mixed with the EC or SC formulations of propanil. No negative interactions were observed when hemp sesbania was treated with any rate of Gambit mixed with either formulation of propanil. In conclusion, this research indicates that Gambit at 22.7 and 55.4 g ha^{-1} co-applied with either the EC or SC formulations of propanil results in decreased control of alligatorweed when compared with Gambit applied alone at the same rates. If growers targeting alligatorweed use broad spectrum mixture of Gambit and propanil, Gambit should be applied at 82.9 g ha^{-1}; however, Gambit alone can be applied at 55.4 g ha^{-1} for similar control.

The Impact of Application Equipment and Methodology on Hexazinone Efficacy for Controlling Smutgrass (Sporobolus Indicus). Mason T. House*[1], Zachary S. Howard[1], Scott A. Nolte[2]; [1]Texas A&M University, College Station, TX, [2]Texas A&M AgriLife Extension, College Station, TX (91)

The broad range of variables involved in herbicide applications can make achieving effective weed control very challenging. These variables include application timing, methodology, weather and many other factors. The impacts of some of these variables have been researched extensively in several weed species; however, no research has been published evaluating application nozzle type and the methodology required to significantly improve smutgrass control. The research presented compares flat-fan air-induction nozzles to bi-directional nozzles by spraying hexazinone through both nozzles in addition to data collected regarding how the location on the plant the hexazinone is applied to impacts hexazinone's efficacy. Both studies were conducted at two locations in Brazos County, TX. The 2019 trial of the nozzle study found that glyphosate at 2.33 L hA^{-1} followed by hexazinone at 5.26 L hA^{-1} resulted in 100% control approximately 1 year after application while not being significantly more damaging to the bermudagrass *(Cynodon dactylon)* within the plots than the untreated check. However, both nozzles resulted in 100% control with this herbicide treatment, which means there was no difference in control that could be contributed to the nozzles. In terms of hexazinone site of application, there was no significant difference in smutgrass control between sites, but there was significant difference in terms of injury to surrounding bermudagrass.

Rice Response and Weed Control of Clomazone Applied at Different Timing in a Continuous Rice Flood System. Aaron Becerra-Alvarez*, Kassim Al-Khatib; University of California - Davis, Davis, CA (92)

The majority of California rice (*Oryza sativa* L.) is grown in a continuous rice flood system where rice is seeded into a field with a ten to twelve centimeter flood. The continuous flood system has led to few adapted, competitive and difficult to control grass and sedge weeds. Difficult to control grass weeds include watergrass (*Echinochloa spp.)* and sprangletop (*Leptochloa fusca).* Emergence of grasses can occur early or later in the season depending on the species. Many growers use clomazone in a micro encapsulated granule at day of seeding to control sprangletop and other early emerging grasses. However, some growers applied clomazone after leathering which is a method used in water-seeded systems by draining the field within the first few days after seeding and re-flooding once the crop has established shallow roots, roughly one week after seeding. This allows for good crop establishment and rooting, but also allows weeds the opportunity to become highly competitive with adequate moisture for germination and low water depths for emergence and rapid development. Cerano® label has a day of seeding application timing with a 14-day water holding period once applied to a field. This study was set to find the effects on rice injury and weed control from applying clomazone at different timing. Clomazone was applied at 450 g ai/ha, 560 g ai/ha and 670 g ai/ha on the day of seeding and seven days after seeding with the flood lowered to a skim and then re-flooded. In both years there was a reduction in yield from the later application of clomazone. There was greater weed control of *Echinochloa spp.* and *Leptochloa fusca* the first year averaging 99 to 100% for all grass species, but poor weed control of *Echinochloa spp.* the second year averaging from 21 to 71%. *Leptochloa fusca* control the second year was decent for the early application from 92 to 95% and 70 to 71% at the later application. Application of clomazone at a later application with a lowered flood increased rice injury and had variable weed control.

Effects of Interseeding Corn and Alfalfa on Weed Population Dynamics. Sarah A. Chu*[1], Erin E. Burns[2]; [1]Michigan State University, Lansing, MI, [2]Michigan State University, East Lansing, MI (93)

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 split-plot 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, PH) or upright (narrow leaf angle, UH) to assess impacts of light penetration on weed dynamics. To establish uniform densities and emergence a surrogate weed, Japanese millet (*Echinochloa esculenta*), was used. Subplots consisted of Japanese millet presence or absence. Glyphosate resistant alfalfa was planted on the same day as the corn. Japanese millet seed production was collected at the end of the season and viability assessed. 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 separated 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 differed between years ($p<0.001$); therefore, years were analyzed separately. In 2019, there was no difference in millet seed production between the two hybrids ($p=0.7$); however, in 2020, seed production decreased in the pendulum hybrid by 68% compared to the upright hybrid ($p=0.04$). Interseeding decreased weed seed viability by 46% compared to monoculture corn average across hybrids and years ($p=0.02$). Mean 2019 population growth rates at year 20 of the projections were 1.97, 1.6, 1.0, and 1.3 for the PH monoculture, UH monoculture, PH interseeded, and UH interseeded, respectively. The 2019 PH interseeded treatment decreased population growth by 49% and 37% compared to the PH and UH monoculture. The 2019 UH interseeded treatment decreased population growth by 34% and 18.8% compared to the PH and UH monoculture. Interestingly, there was no difference in growth rates for PH and UH 2019 interseeded treatments. Interseeding decreased Japanese millet seed production by 99% compared to the monoculture treatments in 2019. Seed production and growth rates crashed rapidly in 2020 due to the lack of precipitation during the establishment. Seed production and overwinter seed survival were the most elastic parameters for the 2019 PH and 2019 UH, respectively. Interseeding corn and alfalfa has the ability to control weeds by limiting the number of viable seeds produced. Furthermore, management tactics that reduce seed production and overwinter seed survival will enhance weed control benefits proved from interseeding corn and alfalfa. burnser5@msu.edu

Confirmation of Widespread 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 (94)

Waterhemp 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 days after treatment (DAT) plants were counted, and biomass harvested. The % count reduction comparing treatments with NTC was estimated. Treatments with count reduction = 90% were classified as satisfactory. 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. Plants with VE = 5 were classified alive and populations with survival = 50% were classified putative-resistant to the treatment of interest. According to our results, reduced PRE rates (0.5x) of atrazine and fomesafen resulted in smaller waterhemp control. Atrazine was the only herbicide that did not provide satisfactory control in PRE (1x: 82% count reduction; mean across populations). Imazethapyr and glyphosate resistance is widespread in WI waterhemp (1x: 35% and 40% biomass reduction, respectively; means across populations). A three-way putative imazethapyr-, glyphosate-, and 2,4-D-resistant waterhemp population was detected in WI and will be further investigated. No population was classified as putative dicamba-, mesotrione-, or glufosinate-resistant. However, random alive plants were observed for these herbicides 21 DAT, except for glufosinate, which provided complete control (100% mortality across all populations investigated). Senior Author Email: rwerle@wisc.edu

Response of Established Peppermint (*Mentha* × *piperita*) to Pyroxasulfone: a Greenhouse Study. Jeanine Arana*, Stephen L. Meyers, Brandi C. Woolam; Purdue University, West Lafayette, IN (95)

Weeds in mint reduce the yield of mint hay, oil, or both. Additionally, weeds contaminate the mint hay and oil, reducing its quality and value. Chemical control is widely used by Indiana mint farmers, but they often rely on only a few herbicides. To provide more herbicide options to Indiana mint farmers, more herbicides need to be evaluated. Pyroxasulfone is registered for use in mint in the Pacific Northwest but not Indiana. To gain a greater understanding of the impacts of pyroxasulfone on peppermint tolerance and yield, a dose-response study was developed. Two greenhouse experiments were conducted at the Purdue University Horticulture Greenhouses, West Lafayette, IN. Experiments consisted of postharvest (PH) and dormant (DORM) applications of pyroxasulfone at four rates (110, 220, 440, and 880 g ai ha^{-1}) plus a non-treated control. Both experiments had two runs separated by time, four replications, and utilized a randomized complete block design. Experimental units consisted of a 20 cm polyethylene pot in which either two rhizomes (PH) or four stem cuttings (DORM) were planted. PH treatments were applied after a simulated harvest of aboveground biomass 134 (Run 1) and 128 days after planting (DAP) (Run 2). At 97 DAP, aboveground biomass was removed from the DORM study, and pots were placed in a cooler at 4°C for 34 (Run 1) and 35 days (Run 2) before applying treatments. Data collection consisted of visual crop injury ratings on a scale of 0% (no injury) to 100% (crop death) and plant height of ten shoots in each pot from the substrate surface to the shoot apical meristem. Mint was harvested 5 (PH) and 8 weeks after treatment (DORM) and dried at 60°C for 3 days. Data were subjected to ANOVA, and a non-linear regression analysis was performed to fit predictive models. In both studies, increasing pyroxasulfone rate from 0 to 880 g ha^{-1} resulted in increased crop injury and decreased plant height and aboveground dry biomass. However, the 1x labeled rate registered in other states (110 g ha^{-1}) resulted in a predicted dry biomass reduction of less than 6% compared to the non-treated control. In conclusion, applying pyroxasulfone at 110 g ha^{-1} is recommended in dormant, established mint. Additional research should be conducted to evaluate other herbicides in established, dormant mint in the Midwest.

Tolerance of Rice Cultivars to Florpyrauxifen-benzyl Followed by Benzobicyclon. James W. Beesinger*, Jason K. Norsworthy, Leonard B. Piveta, Tristen H. Avent; University of Arkansas, Fayetteville, AR (96)

Florpyrauxifen-benzyl was registered in rice in 2018 to combat herbicide-resistant barnyardgrass (*Echinochloa crus-galli*), broadleaf, and aquatic weedy species. Producers began to notice injury to rice following florpyrauxifen-benzyl applications, and became concerned about yield loss, groundcover reduction, and delayed maturity. Anticipation of the registration of benzobicyclon, a 4-hydroxyphenylpyruvate dioxygenase (HPPD) herbicide, used for the control of weedy rice in flooded rice systems, has led to questions regarding rice injury when using benzobicyclon following florpyrauxifen-benzyl. The combination of florpyrauxifen-benzyl and benzobicyclon in a herbicide program has the potential to control several of the most problematic weedy species in rice production. An experiment was conducted to determine if florpyrauxifen-benzyl and benzobicyclon would interact to lead to increased injury to rice over the use of the herbicides alone. The whole plot factor of the experiment was with or without benzobicyclon applied at 371 g ai ha^{-1} applied postflood and the subplot factor was rice cultivar (a pureline medium-grain cultivar 'Titan', a pureline long-grain cultivar 'Diamond', and the hybrid long-grain cultivars 'Gemini 214CL,' 'CL XL745,' and 'XP753'. An additional subplot factor was with or without an application of florpyrauxifen-benzyl at 30 g ae ha^{-1} at the 3- to 5-leaf rice growth stage. Injury ratings on a scale of 0-100% were taken 28 days after application with 0% signifying no plant injury and 100% meaning rice death. Groundcover analysis was determined from photos taken using a drone 35 days after treatment. Photographs were subject to Field Analyzer, which quantified groundcover. Plots were harvested at maturity to determine grain yield. Data analyzed revealed no increased injury when following florpyrauxifen-benzyl with benzobicyclon (21%) than applying florpyrauxifen-benzyl alone (19%). No significant differences were found when yield or groundcover were analyzed. Findings from this trial lead to conclusion that florpyrauxifen-benzyl followed by benzobicyclon is no more injurious than florpyrauxifen-benzyl alone and that visible injury observed after application is transient and unlikely to reduce grain yield.

Rescue Control of Palmer Amaranth (*Amaranthus palmeri*) in 2,4-D Resistant Soybean.
Spencer J. Michael*, Kevin W. Bamber, Michael L. Flessner; Virginia Tech, Blacksburg, VA (97)

Palmer amaranth (*Amaranthus palmeri*) is the most detrimental weed to agronomic cropping systems in the United States largely due to its resistance to multiple sites of action. Due to Palmer amaranth's rapid growth, herbicide applications are frequently made to sizes larger than recommended. A study was conducted in Blackstone, VA to evaluate control options through Enlist traits for Palmer amaranth that survives late into the growing season. Enlist soybeans were planted on 76 cm row spacings in a field infested with glyphosate and ALS resistant Palmer amaranth. Plots were randomized utilizing a complete block design with four replications. Treatments were applied at three timings. Timing A was when Palmer amaranth reached 30.5 cm in height. Application timings B and C were seven and 14 days after application A (DA-A), respectively. Treatments included Enlist Duo (2,4-D + glyphosate) at A, Enlist One + Liberty (2,4-D + glufosinate) at A, Enlist Duo at A followed by (fb) Enlist Duo at B, Enlist One + Liberty at A fb Enlist One + Liberty at B, Enlist Duo at A fb Liberty at B, Liberty at A fb Enlist Duo at B, Enlist Duo at A fb Enlist Duo at C, Enlist One + Liberty at A fb Enlist One + Liberty at C, and Enlist Duo at A fb Liberty at C. Dual II Magnum (*S*-metolachlor) was applied across the entire study at C. Visible Palmer amaranth control ratings were taken 48 and 63 DA-A and soybean yield data were taken at harvest. Data were subject to ANOVA followed by a means separation and contrast statements to determine differences between single applications and sequential applications at separate timings as well as one effective site of action compared to multiple. All treatments except Enlist Duo at A resulted in =90% Palmer amaranth control 48 and 63 DA-A. There was nearly a 12% and 10% increase in Palmer amaranth control 48 DA-A and 63 DA-A (28 and 42 days after timing C) when using two effective SOA's compared to just one. Sequential applications compared to single applications displayed over a 16% increase in control 48 DA-A and over 17% 63 DA-A. There was not a significant difference in control between 12- and 20-day (timings B and C) sequential applications. Sequential applications compared to single displayed a significant increase in yield with an over 334 kg ha^{-1} increase. No other treatments displayed a significant increase or decrease in yield. Controlling large Palmer amaranth requires multiple applications that include multiple, effective sites-of-action. Future research should evaluate seed production and viability resulting from these treatments.

Sensitivity of Fluazifop-Resistant Grain Sorghum to ACCase-inhibiting Herbicides. Jacob A. Fleming*[1], Jason K. Norsworthy[1], Muthukumar V. Bagavathiannan[2], Leonard B. Piveta[1]; [1]University of Arkansas, Fayetteville, AR, [2]Texas A&M University, College Station, TX (98)

Genetic similarities between grasses, such as johnsongrass and grain sorghum, results in difficulty in selectively removing the weed from the crop. Because of these similarities, few effective herbicides are labeled for johnsongrass control in grain sorghum. Through a collaboration between Texas A&M University and the University of Arkansas Division of Agriculture, a line of grain sorghum with resistance to the acetyl CoA carboxylase (ACCase)-inhibiting herbicide fluazifop was developed. A field trial was conducted in 2020 in Fayetteville, AR, to evaluate the sensitivity of fluazifop-resistant grain sorghum to multiple ACCase-inhibiting herbicides. Fluazifop-resistant grain sorghum was sprayed at the 2- to 3-leaf stage with eleven different ACCase-inhibiting herbicides, with fluazifop assessed at three rates and the other herbicides at two rates. The goal was to better understand which herbicides may potentially be useful for control of grasses in the future without injuring the crop. Information gained could also be used to determine if there are any ACCase inhibitors which could be used to control volunteer crop plants in the next cropping season. Overall, a low level of visual injury was observed with applications of ACCase inhibitors within the aryloxyphenoxypropionate (fops) and phenylpyrazolin (dens) families when applied at a 1x rate. Injury caused by herbicide in these families did not exceed 10%, other than a premix of fluazifop + fenoxaprop. Conversely, a high level of visual injury was observed within the cyclohexanedione (dims) herbicides, specifically clethodim and sethoxydim. These findings lead to the conclusion that there are several ACCase-inhibiting herbicides that can be safely used over-the-top of fluazifop-resistant grain sorghum and options for controlling volunteers in subsequent broadleaf crops exist.

Use of Mulches and Herbicides on Non-rooted Cuttings and Their Effect on Root Growth After Transplant. Isha Poudel*, Anthony L. Witcher; Tennessee State University, Mcminnville, TN (99)

Weeds are a major problem in cutting propagation and compete with the main crop for water, sunlight, and nutrients and hence reduce the growth and marketable quality of the rooted cuttings. Due to the high labor cost of hand weeding, pre-emergence herbicides and mulches can be alternative methods for weed control in the propagation environment. The objective was to determine the effect of mulches (rice hulls and pine pellets) and pre-emergence herbicides [isoxaben (Gallery), oxyfluorfen + oxadiazon (Regal O-O), isoxaben + dithiopyr (Fortress), and indaziflam (Marengo G)] on rooting of cuttings and growth after transplant. Terminal and sub-terminal 9-10 cm stem cuttings of crape myrtle (*Lagerstroemia indica 'Catawba'*) were collected from container grown stock plants. Cuttings were then stuck in 6.4 cm diameter containers treated with pre-emergence herbicides and mulches then were kept under intermittent mist. After sufficient rooting had occurred (based on the non-treated control), 8 cuttings (8 replications per treatment) were randomly selected and transplanted to trade gallon (2.4 L) containers. Shoot growth (height and width), leaf greenness (SPAD), and substrate pH and electrical conductivity (EC) were recorded monthly for 3 months. At termination of the study, all plants were harvested to record shoot and root dry weight. The remaining 17 cuttings (from each treatment) were harvested, and data were collected including rooting percentage, root length and volume, and root and shoot dry weight. All data were analyzed with linear models using the GLIMMIX procedure of SAS and differences between treatment means were determined using the Shaffer Simulated method ($P < 0.05$). Rooting percentage was similar to the nontreated control (88%) for all treatments but ranged 80% (isoxaben + dithiopyr) to 96% (oxyfluorfen + oxadiazon). Root growth (length, volume, and dry weight) was similar for all treatments compared to the non-treated control. After transplant, shoot and root growth and SPAD were similar among all treatments after 3 months. Additionally, substrate pH and EC were similar among all treatments. There was no suppression of the root and shoot growth after transplant by any of the pre-emergence herbicides or mulches. In conclusion, certain pre-emergence herbicides and mulches may be viable alternatives for weed control in propagation, but they need to be tested for different crop species. (ipoudel76@gmail.com)

Greenhouse and Laboratory Investigations of an ALS-inhibitor Herbicide-Resistant Fall Panicum Accession from Wisconsin. Jose J. Nunes*[1], Damilola A. Raiyemo[2], Nicholas J. Arneson[1], Patrick Tranel[3], Rodrigo Werle[1]; [1]University of Wisconsin - Madison, Madison, WI, [2]University of Idaho, Moscow, ID, [3]University of Illinois, Urbana, IL (100)

POST-emergence grass control in sweet corn (*Zea mays* L. var. saccharate) production can be a challenge due to the lack of herbicide options. Sweet corn producers typically rely on nicosulfuron (Acetolactate synthase-inhibitor; ALS) as the main effective POST option for grass control. In Wisconsin, a sweet corn producer reported control escapes of fall panicum plants 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-inhibitor resistance in the aforementioned fall panicum accession and evaluate its response to alternative POST herbicide options. Two studies were conducted under greenhouse conditions in a completely randomized design (CRD). Each treatment was replicated 6 times and each experimental unit consisted of 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 28 days after treatment (DAT), 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 a 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 post 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 seeds. Studies also were initiated to understand the molecular basis of resistance. Preliminary data indicate resistance is conferred by an insensitive target site, due to the previously identified amino acid substitution of Asp376Glu. To our knowledge, this is the first confirmation of ALS resistance in fall panicum in the United States.

***Amaranthus palmeri ppo2* (?G210) Mutation Confers Resistance to Preemergence Application of Fomesafen in Rice.** Pamela Carvalho-Moore*[1], Gulab Rangani[1], Shan Zhao[1], Ana Claudia Langaro[2], Vibha Srivastava[1], Nilda Roma-Burgos[1]; [1]University of Arkansas, Fayetteville, AR, [2]Federal University of Rio de Janeiro, Seropedica, Brazil (101)

Resistance to protoporphyrinogen IX oxidase (PPO) herbicides in *Amaranthus palmeri* populations in Arkansas is primarily due to target site mechanisms. Among the PPO-mutations reported thus far, the deletion of glycine at position 210 (*?G210*) is the most common. Little information is available regarding the level of resistance to PPO-herbicides conferred by any mutant PPO in economically important plants. In this study, rice (*Oryza sativa* c. 'Nipponbare') was used as a model crop to assess the resistance level to fomesafen conferred by *A. palmeri ppo2 ?G210*. Transgenic rice overexpressing the *A. palmeri ppo2 ?G210* gene was generated via particle bombardment. PCR-assay confirmed the presence of the transgene in T0 plant, and seeds (T1) were harvested. T1 seedlings were treated with twice the maximum dose of fomesafen labeled for soybean (0.78 kg ha^{-1}) to identify transformants exhibiting low injury. These plants (18 total) were grown to produce T2 seeds. A soil-based assay was conducted with T2 seeds to determine if the presence of the transgene would confer resistance to fomesafen applied preemergence (0.39 kg ha^{-1}). The experiment was arranged in a completely randomized design with three replicates and was conducted twice. Each replication consisted of a flat filled with a 1:1 ratio of field soil and commercial potting soil and eight seeds of either T2 or wild type (WT) rice seeds. Non-treated checks were included. At 3 weeks after treatment, seedling emergence count and injury per emerged seedling (%) were recorded. Germination reduction (%) was calculated relative to non-treated checks. Germination reduction (%) data were analyzed using PROC GLIMMIX function with beta distribution in SAS 9.4. The run x treatment effect was not significant; therefore, the data from two runs were combined, resulting in six replications. The presence of *ppo2* transgene and its level of expression were verified in the T2 survivors. Fomesafen caused 92% and 27% germination reduction in WT and T2, respectively. Injury ranged from 30 to 95% among T2 survivors. All T2 survivors carried and overexpressed the *ppo2* transgene compared to WT plants. Therefore, the *A. palmeri ppo2-?G210* confers resistance to soil-applied fomesafen in rice. This trait could be introduced into high-value crops that lack chemical options for weed management.

Minimizing Off-target Movement of Florpyrauxifen-benzyl to Soybean. Bodie Cotter*, Jason K. Norsworthy, James W. Beesinger, Mason C. Castner, Grant L. Priess; University of Arkansas, Fayetteville, AR (102)

Following commercial launch of Loyant™ (florpyrauxifen-benzyl) in 2018, frequent off-target movement of the herbicide to adjacent soybean (*Glycine max*) fields was observed. Hence, a field experiment was conducted in 2020, in Fayetteville, AR, to compare drift rates (0 to 5.625 g ae ha^{-1}) of florpyrauxifen-benzyl as a foliar spray and impregnated on urea. Applications occurred at the V3 stage. The response of soybean was evaluated when florpyrauxifen-benzyl was applied in a wide-row soybean system at 7, 14, 21, and 28 days after application. Maximum soybean injury observed from a florpyrauxifen-benzyl impregnated urea treatment of 5.625 g ae ha^{-1} 21 days after treatment was 20%. However, the maximum amount of soybean injury observed from a 5.625 g ae ha^{-1} foliar application of florpyrauxifen-benzyl was 100% in wide-row soybean. At all timings, equivalent rates of florpyrauxifen-benzyl impregnated on urea caused less injury than that of the foliar applications. No deleterious effect on yield was observed from any florpyrauxifen-benzyl impregnation treatment when compared to the nontreated, but all foliar treatments caused a negative effect on soybean yield. Overall, florpyrauxifen-benzyl impregnated urea applications reduced soybean injury 50% to 91% in wide-row soybean, across all intervals when compared to foliar applications. Impregnating florpyrauxifen-benzyl to urea will likely mitigate the risk for off-target movement of the herbicide that would result in high levels of soybean injury.

Field Surveys for Assessing Weed Seedbank Additional Potential and Feasibility of Harvest Weed Seed Control in Texas Rice. Isidor Ceperkovic*[1], Xin-Gen Zhou[2], Muthukumar V. Bagavathiannan[1]; [1]Texas A&M University, College Station, TX, [2]Texas A&M University, Beaumont, TX (103)

Herbicide-resistant weeds are becoming a serious issue in rice production in Texas, and the need for developing and implementing integrated weed management (IWM) strategies is increasingly vital. Harvest weed seed control (HWSC) is an emerging IWM tool, but the success of this approach depends greatly on the ability of weeds to retain seeds at the time of harvest. A late-season weed survey was conducted in Texas rice fields during the harvest window of 2020, to identify dominant weed species present as escapes, estimate seed rain potential, and determine seed shattering for each of those species. The survey was conducted in eight counties of the Texas Gulf Coast region and included 50 rice fields. These fields were selected randomly on a Google® Map without any prior knowledge of the presence of weed escapes. Data showed that 23 of the 50 surveyed fields had substantial densities of weed escapes. Barnyardgrass, junglerice, Nealley's sprangletop, weedy rice, and broadleaf signalgrass were the most common and dominant species in the infested fields. Barnyardgrass had the highest average seed rain potential across 23 fields with 109.3 million seeds ha^{-1}, while broadleaf signalgrass had the lowest average seed rain potential of 89.4 million seeds ha^{-1}. The data showed that weedy rice had the highest average seed shuttering potential of 6.8%, while Nealley's sprangletop had the lowest, at 4.4%.

Weed-suppressive Potential of Sweetpotato Cultivars on Targeted Weed Species. Isabel S. Werle*[1], Matheus Machado Noguera[1], Pamela Carvalho de Lima[1], Jeremie Kouame[1], Te-Ming (Paul) Tseng[2], Nilda Roma-Burgos[1]; [1]University of Arkansas, Fayetteville, AR, [2]Mississippi State University, Mississippi State, MS (104)

Sweetpotato (*Ipomoea batatas* L.) has a creeping growth habit with a long duration before canopy closure, favoring high weed competition. Few herbicides are registered for small-acreage crops like sweetpotato so growers rely primarily on nonchemical methods for weed control. Screening for weed-suppressive sweetpotato genotypes is a sustainable alternative towards weed management. The objective of this study was to evaluate the weed-suppressive ability of sweetpotato cultivars on key weed species. A greenhouse study was conducted with nine sweetpotato cultivars and target weeds Palmer amaranth (*Palmer amaranth* S. Wats), junglerice (*Echinochloa colona* L.), and hemp sesbania (*Sesbania herbacea* Mill.) over four weeks. Six sweetpotato vines,15 cm long, were planted into a sand medium. The target weeds were planted in pots filled with field soil medium and watered with leachates from the sweetpotato cultivars. The sweetpotato pots were placed in a bucket to catch the leachate and watered with the same volume once every two days. The leachates were collected and applied in 100-ml aliquots to the target weed species. Seedling emergence was recorded and four plants were retained per pot to evaluate growth. Plant heights were measured once weekly. Fresh biomass of sweetpotato root and shoot were quantified as well as shoot biomass of the weeds. The experimental design was a randomized complete block, with four replications. The study was conducted twice. Data were analyzed using JMP 15.2.0 (SAS Institute Inc., Cary, NC). Cultivar 22 and 43 reduced the emergence of Palmer amaranth by 42 and 35%, respectively. The inhibition of junglerice germination ranged from 7 to 21% across cultivars, while inhibition of hemp sesbania germination ranged from 17 to 25%. Hemp sesbania and junglerice emergence did no differ across cultivars. Cultivars 28 and 29 had the highest shoot/root ratio, 6.41 and 6.29, respectively while cultivar 5 had the smallest ratio (3.18). Sweetpotato leachates had the largest effect on weed seedling height in the first week, except on Palmer amaranth. Cultivar 43 caused the most stunting of junglerice and Palmer amaranth, 29%, and 11%, respectively. Hemp sesbania height was reduced up to 10% with cultivars 32 and 33. Shoot biomass of junglerice and Palmer amaranth was reduced the most with cultivars 43 and 5. Cultivar 17 reduced hemp sesbania biomass about 19%. Therefore, sweetpotato cultivars differ in weed-suppressive ability. Cultivars 5, 17, and 43 had the highest potential to suppress the target weed species. The largest effect of sweetpotato leachates was on the reduction of Palmer amaranth emergence. In terms of weed growth, root leachates of sweetpotatoes were most inhibitory to young seedlings of all species tested. Sweetpotato growers will benefit from this information to select robust genotypes for their farming operation.

Effect of Surfactants on Postemergent Applications of Glyphosate and Glufosinate on Palmer Amaranth (*Amaranthus palmeri*) and Kochia (*Bassia scoparia*). Ely D. Anderson*[1], Bruno C. Vieira[1], Susan Sun[2], Greg Kruger[1]; [1]University of Nebraska - Lincoln, North Platte, NE, [2]Croda Inc., New Castle, DE (105)

Glufosinate tank-mixed with glyphosate could help with controlling problematic weeds and prevent herbicide resistance among targeted weeds by providing two modes of action in a tank-mixture. However, previous research shows that tank-mixing glufosinate with glyphosate can be antagonistic. Surfactants have been shown to help overcome herbicide antagonisms. The addition of a surfactant could help with overall weed control and help prevent antagonistic results when tank-mixing these chemistries. Field research was conducted through The University Nebraska-Lincoln at the West Central Research, Education, and Extension Center in North Platte, Nebraska and the Panhandle Research and Extension Center in Scotts Bluff, Nebraska to better understand the interaction between unformulated glufosinate and unloaded glyphosate alone, tank-mixed, and in combination with two proprietary anionic surfactants: S1 and S2. Palmer amaranth (*Amaranthus Palmeri*) was the target species in North Platte and kochia (*Bassia scoparia*) was targeted in Scotts Bluff. Treatments were applied using a CO2 backpack sprayer calibrated to deliver 140L ha^{-1} using TTI11002 nozzles at 276 kPa when plants reached a height of 10-15 cm. 28 days after treatment 10 plants from each plot were selected at random and above ground biomass was harvested and oven dried (65 C) to constant weight. 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 herbicide by surfactant were significant (p-value = 0.0038). The greatest weed control observed on Palmer amaranth came from a tank-mixture of unformulated glufosinate and unloaded glyphosate with S1 (46%). Adding S1 (3%) or S2 (0%) to unloaded glyphosate alone resulted in a decrease in control of Palmer amaranth compared to unloaded glyphosate alone (22%). At the Scotts Bluff location, there were no differences observed amongst treatments. Overall, adding a surfactant to a tank-mixture of glufosinate with glyphosate could result in greater weed control depending on the target weed species

Metribuzin Tolerance of Winter Wheat Varieties in Oklahoma. Lane S. Newlin*[1], Misha R. Manuchehri[1], Brett F. Carver[1], Amanda De Oliveira Silva[1], Hannah C. Lindell[1], Justin T. Childers[2], Caitlyn C. Carnahan[1]; [1]Oklahoma State University, Stillwater, OK, [2]Oklahoma State University, Marlow, OK (106)

Metribuzin is a herbicide that is still widely used in cropping systems annually. However, its use in winter wheat in Oklahoma has declined due to varietal sensitivity or lack of information regarding the topic. To evaluate modern winter wheat varieties, a trial was conducted at Fort Cobb and Perkins, Oklahoma in the fall of 2019. Winter wheat varieties Fusion AX, Showdown, Strad CL Plus, and Uncharted were evaluated. Treatments consisted of two herbicide tank mixtures and a control. Mixtures included pyroxasulfone at 119 g ai ha^{-1} plus 105 or 210 g ai ha^{-1} of metribuzin. Herbicide mixtures were applied PRE or delayed PRE (wheat spike). Visual wheat injury, biomass, and crop yield were recorded. For peak visual crop injury at Fort Cobb, an application timing by rate of metribuzin interaction occurred where visual injury increased by 25% at the high rate when applied at the PRE timing compared to the delayed PRE. Peak visual injury at Perkins indicated a variety by rate of metribuzin interaction where Fusion AX and Uncharted at the high rate resulted in greater visual injury compared to Showdown and Strad CL Plus at the high rate of metribuzin. Showdown was the only variety where there was no visual injury difference between the low and high rate. For yield at Fort Cobb, an application timing by rate of metribuzin interaction showed no significant reduction in yield across delayed PRE treatments; however, at the PRE application timing, yield decreased as rate increase. For yield at Perkins, a variety by metribuzin rate interaction occurred where compared to the nontreated, there was a reduction in yield for Strad CL Plus following the low metribuzin rate. Following the high rate compared to the control, there was a reduction in yield for all varieties except Showdown. Results suggest that metribuzin can be used in winter wheat to effectively control economically important grass weeds, but soil type, variety, application timing, and rate must be considered. lane.newlin@okstate.edu

Season-Long Horseweed (*Erigeron canadensis* L.) Suppression with Fall-Seeded Cereal Cover Crops and Narrow Soybean Row Widths. Justine L. Fisher*, Christy Sprague; Michigan State University, East Lansing, MI (107)

Glyphosate-resistant horseweed (*Erigeron canadensis* L.) is a problematic weed for Michigan soybean growers. Previous research has demonstrated increased weed suppression when cover crop biomass is high at termination. The combination of fall-planted cereal cover crops and planting soybean in narrow row widths may reduce horseweed growth and lead to season-long horseweed suppression. Two separate field experiments were conducted in 2020 to investigate the effects of fall-seeded cereal cover crops and soybean row width on horseweed suppression. In October 2019, cereal rye was planted at the recommended seeding rate of 67 kg ha^{-1} in the first experiment and winter wheat was planted at a higher seeding rate of 161 kg ha^{-1} in the second experiment. Each experiment was setup in a split-plot randomized complete block design with cover crop termination timing as the main plot and soybean row width as the subplot. Cereal rye and winter wheat were terminated with glyphosate at 1.27 kg ha^{-1} one week prior to ('early termination') and one week after ('Planting Green') planting 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. Horseweed emerged primarily after soybean planting and continued throughout the season; therefore, at the time of early termination there were no differences in horseweed density between the cover crop and no cover treatments in both experiments. Cereal rye biomass was 2,064 kg ha^{-1} at early termination and was 2.6-times higher (5,349 kg ha^{-1}) at the 'Planting Green' termination time. Biomass of early terminated winter wheat was 3,188 kg ha^{-1} and was 2.9-times higher (9,211 kg ha^{-1}) by 'Planting Green'. Horseweed biomass was 59 and 94% lower in cereal rye plots terminated early and at 'Planting Green', respectively, compared with no cover, 4 weeks after planting (WAP). Horseweed density was also 93% lower in the 'Planting Green' plots. Horseweed biomass was 95 and 99% lower when winter wheat was terminated early and by 'Planting Green' compared with no cover, respectively, 4 WAP. The combination of narrow row soybean (19- and 38-cm) and early termination also reduced horseweed density more than planting soybean in 76-cm rows for early terminated winter wheat. However, soybean row width did not affect horseweed density when 'Planting Green'. At soybean harvest, horseweed biomass was 27 and 50% lower by 'Planting Green' into cereal rye compared with early termination and no cover, respectively. In addition, horseweed biomass was lower in 19-cm rows compared with 76-cm rows. At the winter wheat location, horseweed biomass at harvest was 49 to 60% lower in the no cover plots when soybean was planted in narrow rows. However, soybean row width had no effect on horseweed biomass when the winter wheat cover was terminated early or by 'Planting Green'. The winter wheat cover reduced horseweed biomass at harvest 75% or greater, regardless of termination timing or soybean row width. In conclusion, delaying cover crop termination by 'Planting Green' produced higher cover biomass and reduced horseweed biomass and density until soybean harvest; however, by planting a cereal cover crop at a higher seeding rate, early terminated winter wheat also equally reduced horseweed biomass at the time of harvest. The addition of narrow rows in the cereal rye experiment reduced horseweed biomass compared with wide rows at the time of harvest; however, planting soybean in narrow rows only reduced horseweed biomass when no cover was present in the winter wheat experiment. Suggesting that the higher cover crop biomass observed from planting winter wheat at a higher seeding rate, overwhelmed any effect that narrow row soybean would have on horseweed suppression. These cultural practices have a positive influence on suppressing horseweed that could help with an overall horseweed management strategy.

Weed Management Systems in XtendFlex Soybean. Adam L. Constine*, Christy Sprague; Michigan State University, East Lansing, MI (108)

Herbicide-resistant weeds continue to challenge soybean growers across the United States. Traditional soybean technologies offer growers limited options for glyphosate-resistant (GR) weed control. New soybean technologies, such as Bayer's XtendFlex soybean, provide growers the flexibility to use multiple effective herbicide sites of action for weed control. XtendFlex soybean are resistant to glyphosate, glufosinate, and dicamba. Three field experiments were conducted in 2019 and 2020 to evaluate control of GR-waterhemp (*Amaranthus tuberculatus*), GR-horseweed (*Erigeron canadensis*), and several non-GR weeds in XtendFlex soybean. Twenty different herbicide treatments were evaluated for waterhemp control using PRE followed by POST or EPOS followed by LPOS applications. Flumioxazin at 72 g ha^{-1} was the PRE herbicide used in this study. EPOS, POST, and LPOS applications included glyphosate (1.3 kg ae ha^{-1}), glufosinate (0.65 kg ha^{-1}), dicamba (0.56 kg ha^{-1}), acetochlor (1.3 kg ha^{-1}), and fomesafen (0.28 kg ha^{-1}) applied alone and in various combinations. Similar treatments were evaluated for non-GR weed control in a separate study. In no-till soybean, eighteen herbicide treatments were examined for horseweed control. Dicamba (0.56 kg ha^{-1}) + metribuzin (0.3 kg ha^{-1}) + glyphosate (1.3 kg ae ha^{-1}) or glyphosate alone was applied 14 d prior to planting (EPP) as the base treatments prior to several different POST herbicide treatments. These treatments included: glyphosate (1.3 kg ae ha^{-1}), glufosinate (0.65 kg ha^{-1}), or dicamba (0.56 kg ha^{-1}) applied alone or in combination. Additional EPP treatments included commercial non-dicamba standards. In 2019, all PRE flumioxazin followed by POST treatments provided greater than 90% waterhemp control, with the exception of glyphosate POST (63%), 28 d after treatment (DAT). If two effective herbicide sites of action were applied separately or in tank-mixtures waterhemp control was greater than 90%, while treatments with only one effective site of action provided 78-80% control. Overall, waterhemp control was greatest from PRE followed by POST treatments compared with the 2-pass POST treatments, 56 days after planting (DAP). However, by 70 DAP there were no differences between these systems. There were very few differences in horseweed control. Treatments that contained glufosinate POST following an effective EPP treatment containing metribuzin resulted in greater than 99% control, 14 DAT; while POST glyphosate, dicamba, and glyphosate + dicamba following an effective EPP treatment provided 93-96% control 14 DAT. At soybean harvest, all POST treatments, except glyphosate only, that followed an effective EPP treatment provided >98% horseweed control. For non-GR weeds, the addition of dicamba to glufosinate POST reduced control of annual grass species from 96% to 79%, 14 DAT. The addition of acetochlor to this tank-mixture POST reduced annual grass control even further (64%). Common lambsquarters (*Chenopodium album*), Powell amaranth (*Amaranthus powellii*), and common ragweed (*Ambrosia artemisiifolia*) control were greater than 90% with all treatments 14 DAT. Overall weed control in XtendFlex soybean was excellent when at least one effective herbicide was used in two separate applications. However, caution should be taken with certain tank-mixtures, since antagonisms have been observed, especially on grass weeds.

Interaction of Glyphosate and Dicamba Tank Mixtures on Glyphosate-resistant Horseweed (*Erigeron canadensis*) and Barnyardgrass (*Echinochloa crus-galli*) Control. Estefania Gomiero Polli*[1], Leandro H S Guimaraes[1], Jose H. de Sanctis[2], Guilherme Sousa Alves[1], Greg Kruger[1]; [1]University of Nebraska - Lincoln, North Platte, NE, [2]University of Nebraska - Lincoln, Lincoln, NE (109)

Glyphosate and dicamba tank mixture has been largely adopted for broad-spectrum weed control since the release of dicamba/glyphosate-resistant (DGR) soybean on the market in 2017. However, the effect of those herbicides in combination is not clearly understood. Previous research has shown antagonistic interactions between glyphosate and dicamba. This study was elaborated to further investigate the interaction of glyphosate and dicamba tank mixture combinations on glyphosate-resistant (GR) horseweed and barnyardgrass control. Greenhouse experiments were conducted at the Pesticide Application Technology Laboratory in North Platte, NE. Herbicide treatments consisted of combinations of glyphosate at 0, 316, 630, 1260, 1900, and 2530 g ae ha^{-1} and dicamba at 0, 140, 280, 560, 840, and 1120 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 and two runs. At 28 days after application (DAA), above-ground biomass was harvested and oven-dried at 65 C until constant weight. Colby analysis was conducted to evaluate the nature of herbicide interactions, expected and observed biomass reduction values for each herbicide combination were subjected to t-tests to determine whether means differ at a=0.05. GR horseweed biomass reduction varied from 59% to 77% regardless of the herbicide treatment and, antagonistic interactions were observed throughout the majority of treatments. For example, glyphosate at 1260 g ae ha^{-1} plus dicamba at 560 g ae ha^{-1} resulted in 72% of biomass reduction, compared to 81% from the estimated biomass reduction. For barnyardgrass, due to its high susceptibility to glyphosate, all glyphosate rates with 630 g ae ha^{-1} or more resulted in >91% biomass reduction. However, antagonistic interactions were observed within the reduced glyphosate rates. For instance, glyphosate at 316 g ae ha^{-1} plus dicamba at 560 g ae ha^{-1} resulted in 64% of biomass reduction, compared with 85% from estimated biomass reduction which corresponds to a 21% reduction in control.

Influence of Cover Crop Termination Timing with Soil Residual Herbicides on Palmer Amaranth Control in No-till Soybean. Isaac N. Effertz*[1], Vipan Kumar[2], Anita Dille[1], Augustine Obour[2]; [1]Kansas State University, Manhattan, KS, [2]Kansas State University, Hays, KS (110)

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.

Testing Redekop® Seed Destructor for Managing Herbicide-Resistant Waterhemp Seed Bank at Soybean Harvest in Iowa. Alexis L. Meadows*, Prashant Jha, Ramawatar Yadav, Avery J. Bennett, Ryan Hamberg, Edward Dearden; Iowa State University, Ames, IA (111)

Evolution of multiple herbicide resistance in waterhemp is an increasing concern for soybean producers in Iowa and across the Midwest. There is an urgent need to develop integrated weed management strategies, such as harvest weed seed control (HWSC). Mechanical destruction of weed seeds collected by the combine using high-impact mills holds promise in managing herbicide-resistant weeds in soybean. We conducted the first testing of the Redekop™ seed destructor unit integrated into a John Deere S680 combine in soybean fields in Iowa. The technology is designed with a reversible cage mill and added blade system to destroy weed seeds that enters the unit. The objectives of this research were to: (1) quantify the amount of waterhemp seed being lost to the combine header; and (2) evaluate the efficacy of waterhemp seed destruction after seeds passed through the destructor unit at soybean harvest. Experiments were conducted in a randomized complete block design with four replications in grower fields located in Gilbert, IA in 2020. Fields had a high density of waterhemp plants that escaped in-season herbicide applications. Waterhemp seed retention averaged 78% at soybean harvest. Aluminum pans were placed between soybean rows beneath the female waterhemp plants. After the combine header passed over the pans, pans were removed and number of seeds collected were counted. The efficacy of the seed destructor unit was determined by collecting the chaff material (containing weed seeds that passed through the unit) in buckets directly behind the unit. Waterhemp seed was separated from the soybean chaff. Percent seed destruction was visually assessed under a microscope and divided into four categories based on the amount of physical destruction (% visible injury). The four categories included: no destruction (0% visible injury), minimal destruction (10% injury), moderate destruction (60% injury), and severe destruction (90% injury). Seeds were germinated at 25 C for 4 weeks in an incubator and any non-germinated seed was tested for viability using a crush test. Results indicated that the header loss accounted for 33% of waterhemp seed loss at soybean harvest. Ten percent of the total seeds that passed through the seed destructor had no physical damage, 7% had minimal damage, 17% had moderate damage, and 66% had severe physical damage. Seed viability of minimal-damaged seeds was reduced by 39% average compared to non-damaged seeds; however, percent germination did not differ. None of the moderately or severely damaged seed was viable. Overall, seeds that passed through the seed destructor unit had an average of 84% reduction in seed viability compared to seed that did not pass through the unit. Future research will also quantify the loss of waterhemp seeds that escape the seed destructor unit or the straw chopper (thresher loss). In conclusion, the seed destructor would be an effective HWSC technology in soybean to manage herbicide-resistant waterhemp seed banks.

Potential Sweetpotato Yield Losses Due to Weeds. Fnu Chitra*[1], Sushila Chaudhari[2], Katherine M. Jennings[1], Stephen L. Meyers[3], Mark W. Shankle[4], A Stanley Culpepper[5], Mark VanGessel[6], Charlie W. Cahoon[1], Donnie Miller[7], Levi D. Moore[1], Shawn C. Beam[8], Nilda Roma-Burgos[9]; [1]North Carolina State University, Raleigh, NC, [2]Michigan State University, East Lansing, MI, [3]Purdue University, West Lafayette, IN, [4]Mississippi State University, Verona, MS, [5]University of Georgia, Tifton, GA, [6]University of Delaware, Georgetown, DE, [7]Louisiana State University AgCenter, St .Joseph, LA, [8]Virginia Tech, Blacksburg, VA, [9]University of Arkansas, Fayetteville, AR (112)

Weed interference is one of the major causes of yield loss in sweetpotato in the United States. Yield-loss estimates were determined from comparative, quantitative observations of sweetpotato yields between weedy treatments and treatments providing greater than 95% weed control in studies conducted in North Carolina, Mississippi, Georgia, Delaware, Virginia, Louisiana, and Arkansas from 2005 to 2019. Most of the data were from North Carolina (n = 52) and Mississippi (n = 40), which are the major producers of sweetpotato in the US. Primary weeds species reported were Palmer amaranth [*Amaranthus palmerii*] (n = 61), annual grasses (n = 16), redroot pigweed [*Amaranthus retroflexus*] (n = 13), and yellow nutsedge [*Cyperus esculentus*] (n =11). Sweetpotato production and price data from USDA National Agricultural Statistics Service (2018) was used. The average calculated yield loss of marketable sweetpotato was 70%. In North Carolina, the average potential loss was 72%, which was equal to US $189 million and in Mississippi, the average yield loss was 71%, valued at US $58 million.

Monitoring the Frequency and Distribution of Herbicide-Resistant Waterhemp (*Amaranthus tuberculatus*) Populations in Iowa. Ryan C. Hamberg*, Prashant Jha, Ramawatar Yadav, Avery J. Bennett, Alexis L. Meadows, Edward S. Dearden, Iththiphonh A. Macvilay; Iowa State University, Ames, IA (113)

Herbicide-resistant waterhemp [*Amaranthus tuberculatus* (Moq.) Sauer] has spread rapidly over the last decade, creating a nearly insurmountable problem for corn and soybean producers in the Midwest. There is a need to understand the current status of herbicide-resistant waterhemp to design effective weed management programs. In the fall of 2019, we collected seed samples of 200 waterhemp populations from georeferenced corn and soybean fields in Iowa, these same fields were used in a previous survey in 2013. The objective of this research was to determine the temporal (2019 vs. 2013) changes in resistance frequency and distribution of herbicide-resistant waterhemp in Iowa. Each population was screened with eight different herbicide sites of action used in corn/soybean including, ALS (imazethapyr), PS II (atrazine), PPO (lactofen), HPPD (mesotrione), EPSPS (glyphosate), glufosinate, and auxinic (2,4-D, and dicamba). The first five herbicides were tested at 1X (field-use rate) and 4X rates, while glufosinate, 2,4-D and dicamba were tested at 1/2X and 1X rates. Applications were made inside a cabinet spray chamber calibrated to deliver 187 L ha^{-1} when plants were 5- to 6-cm tall. For each population and herbicide dose, 30 plants (10 plants per replication; 3 replications) were sprayed. Experiments were conducted in a randomized complete block design and repeated. Percent visible injury (0 to 100%) was recorded at 14, 21 and 28 days after application (DAA) and a binomial response (dead/alive) of plant survival was recorded at 28 DAA. Data analyzed using PROC MIXED in SAS. The resistance threshold used was 20% survival to the 4X rate and 30% survival to the 1X rate. Out of the 30 georeferenced populations from the 2019 collection, >99% were confirmed resistant to the 4X rate of ALS, 77% resistant to the 4X rate of atrazine, and 90% resistant to the 4X rate of glyphosate. The survival frequency (above the 30% threshold) was 20%, 14% and 29% for 2,4-D, dicamba, and glufosinate, respectively, at 28 DAA, indicating a reduced sensitivity to those herbicides in the 2019 collection. In 2013, 54% of the populations were resistant to the 4X rate of glyphosate which increased to 90% in 2019. The frequency of resistance to atrazine in those populations increased from 63% in 2013 to 77% in 2019. None of the evaluated populations were resistant to either PPO or HPPD herbicides (4X rate) in 2013 but 3% of those were resistant to both herbicide groups in 2019. In 2013, only 3% of those populations were 4-way multiple-resistant, which increased to 13% in 2019. In conclusion, there is an apparent increase in resistance frequency to glyphosate, atrazine, HPPD-, and PPO-inhibitor herbicides and an increase in multiple resistance in Iowa waterhemp populations over the 6-year period. Survivors from the field-use rate of 2,4-D, dicamba, and glufosinate were grown in the greenhouse to obtain seeds for conducting dose-response studies. The impact of herbicide use patterns and other management practices overtime on the development of waterhemp resistance in those fields will be determined. There is an urgent need for the implementation of ecologically based, multi-tactic strategies, to slow down further development of multiple herbicide-resistant waterhemp in corn-soybean production systems of the Midwest.

***Poa annua* (Annual Bluegrass) Presents a Large Diversity of Mutations That Endow Target-Site Resistance.** Claudia A. Rutland*[1], Nathan D. Hall[1], James D. McCurdy[2], Lambert B. McCarty[3], James Brosnan[4], Travis Gannon[5], Daniel Hathcoat[6], Muthukumar V. Bagavathiannan[6], Joseph S. McElroy[1]; [1]Auburn University, Auburn, AL, [2]Mississippi State University, Starkville, MS, [3]Clemson University, Clemson, SC, [4]University of Tennessee, Knoxville, TN, [5]North Carolina State University, Raleigh, NC, [6]Texas A&M University, College Station, TX (114)

Poa annua is evolving resistance to herbicides at an incredible pace in managed turfgrass. To date, *P. annua* has evolved resistance to all major herbicide modes of action used to control it in turfgrass. A multistate project was conducted as part of a USDA Specialty Crop Research Initiative grant to collect and evaluate *P. annua* populations for herbicide resistance. As part of this evaluation, all populations confirmed resistance from a first-phase evaluation were sequenced for known target-site mutations. The most common single nucleotide polymorphisms (SNPs) with known association with target-site resistance (TSR) identified were Pro106 for EPSPS, Trp574 for ALS, Thr239 for alpha-tubulin, and Ser264 for psbA. These SNPs are defined as mechanisms for target-site resistance (TSR) as they are specific mutations that inhibit herbicides from properly interacting with target site. In populations collected from the southeastern region of the United States, 55 out of 85 resistant EPSPS populations containing a mutation at Pro106 and 79 out of 136 resistant ALS populations containing a mutation at Trp574, while only 34 out of 104 resistant psbA populations containing a mutation at Ser264, and 18 out of 60 alpha-tubulin populations containing a mutation at Thr239. Resistant populations showed no mutation for 13 populations for EPSPS, 50 for ALS, 56 for EPSPS, and 0 for alpha-tubulin, while sequencing still needs to be performed on 17, 7, 14, and 42 populations respectively. While no new mutations were encountered, this study provides sufficient evidence that TSR is the more common herbicide resistance for populations resistant to EPSPS and ALS herbicides over nontarget-site resistance, while NTSR seems more common in psbA. Further sequencing should be performed in alpha-tubulin to make a definitive claim on the predominant type of resistance, however it leans toward TSR give there were 0 resistant populations with no mutation present.

***Poa annua* (Annual Bluegrass) Species Response to Preemergence Herbicides with Differing Target-Site Mutations.** Eli C. Russell*; Auburn University, Auburn, AL (115)

Poa annua is a problematic weed that infests golf courses, sports fields, and home lawns. Mitotic inhibiting herbicides are often used to control *Poa annua* in these affected areas. However, resistance to mitotic-inhibiting herbicides has developed due to unaltered herbicide regimes. Suspected resistant populations were collected from across the state of Alabama and screened for resistance to prodiamine. Populations were then sequenced for known target-site mutations located on the alpha-tubulin gene. Two mutations were discovered that had been previously reported to confer resistance to dinitroaniline herbicides in other plants. The first mutation was at position 239 resulting in an amino acid change from threonine to isoleucine and the second mutation was at 268 resulting in an amino acid substitution from methionine to threonine. Different combinations of these mutations were observed in five different populations of *Poa annua.* The results from this study indicated that these mutations confer resistance to prodiamine and cross-resistance to dithiopyr. The IC50 obtained from dose-response trials values indicated that different mutations resulted in varying levels of resistance when compared to a known susceptible population. The level of resistance indicated by regression models and IC50 values ranged from 2 to 16-fold resistance to prodiamine when compared to the susceptible population. The level of resistance for dithiopyr ranged from 9 to 45-fold resistance when compared to the susceptible population. These results indicate resistant populations required more prodiamine and dithiopyr for control compared to the susceptible population.

Integrated Management of Rescuegrass (*Bromus catharticus*) in Grain Only Winter Wheat Production in the Southern Great Plains. Hannah C. Lindell*[1], Misha R. Manuchehri[1], Todd A. Baughman[2], Emi Kimura[3], Gary Strickland[4], David Graf[5], Brett F. Carver[1], Lane S. Newlin[1], Justin T. Childers[1], Caitlyn C. Carnahan[1]; [1]Oklahoma State University, Stillwater, OK, [2]Oklahoma State University, Ardmore, OK, [3]Texas A&M University, Vernon, TX, [4]Oklahoma State University, Altus, OK, [5]Texas A&M University, Iowa Park, TX (116)

Rescuegrass (*Bromus catharticus)* is an early emerging winter annual grass weed species prevalent in winter wheat production of the southern Great Plains. Growers can successfully manage rescuegrass in herbicide tolerant wheat systems; however, control in non-herbicide tolerant wheat often is poor. To evaluate integrated management of rescuegrass, a study was conducted at Marshall, Oklahoma and Burkburnett, Texas to assess an early, mid, and late planting date, one high-competitive and one low-competitive wheat variety, and two common herbicides, sulfosulfuron at 35.2 g ai ha^{-1} and pyroxsulam at 18.4 g ai ha^{-1}. The early planting date represented an optimal sowing window for grain only production. At Marshall, mid and late planting dates decreased rescuegrass biomass 19 and 23 g per 0.25 m^{-2}, respectively, compared to the early planting date. At Burkburnett, a reduction in downy brome (*Bromus tectorum*) biomass was observed for the late planting date, reducing biomass by 28 and 38 g per 0.25 m^{-2} more than mid or early (optimal) dates, respectively. Pyroxsulam controlled rescuegrass the greatest at Marshall by decreasing biomass 28 g per 0.25 m^{-2} more than sulfosulfuron. At Burkburnett, there was no difference in rescuegrass biomass following sulfosulfuron or pyroxsulam, but sulfosulfuron did provide a decrease in biomass compared to the nontreated control while pyroxsulam did not. A decrease in downy brome biomass also was similar following sulfosulfuron and pyroxsulam but both treatments reduced biomass compared to the control. Treatments of pyroxsulam or sulfosulfuron and a delay in planting by two to six weeks after the early sowing time did provide a reduction in rescuegrass biomass.
hannah.lindell@okstate.edu

Efficacy of Chaff-Lining in Managing Herbicide-Resistant Waterhemp (*Amaranthus tuberculatus*) Seedbanks. Avery J. Bennett*, Prashant Jha, Alexis L. Meadows, Ramawatar Yadav, Ryan Hamberg, Edward Dearden; Iowa State University, Ames, IA (117)

Evolution of multiple herbicide resistance (up to 7-way) in waterhemp [*Amaranthus tuberculatus* [(Moq.) J. D. Sauer] is an increasing threat to soybean-based systems. There is an urgent need to develop non-chemical weed management tactics, including harvest weed seed control (HWSC). Chaff lining is one of the most inexpensive HWSC methods widely adopted in Australia to combat HR weeds. The objectives of this research conducted in 2019-2020 at the Iowa State University, Ames, IA were to determine: (1) percent waterhemp seed retention at soybean harvest; (2) efficacy of chaff lining at soybean harvest using a simple insert in the combine that keeps chaff separate from straw, and then places the chaff behind the combine; and (3) effect of soybean chaff on waterhemp emergence. Field experiments (objectives 1, 2) were conducted in a randomized complete block design with four replications, two locations (Ames and Roland, IA). Three different levels of late-season waterhemp densities (seed inputs) were established (using herbicides) at soybean harvest. Data on percent waterhemp seed retention were collected (7-d interval) from seed set to soybean harvest. Waterhemp seed loss due to the combine header (11-meter wide) was determined (no. m^{-2}). Seeds present in the chaff fraction (chaff liner chute) or in the straw fraction (chopper material) were counted (no. m^{-2}). Data on waterhemp late-season density, seed production m^{-2}, percent seed retention, percent header loss, and chaff-lining efficacy analyzed using PROC MIXED in SAS. In greenhouse experiments (randomized complete block design with four replications, two runs), eight soybean chaff rates from 0 to 692 kg ha^{-1}, representing different soybean yields in IA, were used to quantify the effect of different amounts of soybean chaff on waterhemp emergence. Emerged seedlings were counted and removed (3-d interval) for 6 wk after planting. A three-parameter log-logistic model in *R* was fitted to percent cumulative waterhemp emergence data. Late-season waterhemp densities did not influence the percent seed retention by waterhemp, header loss at harvest, or efficacy of chaff lining. Seed retention by waterhemp plants was 95% on September 20 and 78% on October 1, 2020 (harvest date). The header loss at harvest averaged 33.18%. Out of the remaining 66.82% of waterhemp seeds entering the combine, >95% (efficacy) were placed within the chaff line (46-56 cm wide by 16-21 cm deep) at the center of the 11-meter harvested width, and only 1-2% of seeds were lost in the straw fraction (spread out of the straw chopper). Results from greenhouse studies indicated that soybean chaff of 396 kg ha^{-1}, equivalent to 2,690 kg ha^{-1} grain yield, reduced emergence of waterhemp by =80% compared to no-chaff treatment at 6 WAP. Chaff of 594 kg ha^{-1}, equivalent to 4035 kg ha^{-1} grain (average yield of soybean in Iowa), reduced emergence of waterhemp by =95%. Field research in 2021 will determine the fate of weed seeds within the chaff line and how best to manage waterhemp within this band. Overall, this research demonstrates that the HWSC method of chaff lining offers a great opportunity for U.S. soybean growers to manage and reduce spread of HR waterhemp.

Pumpkin Growth and Yield Response to Simulated Dicamba Drift. Lindsey M. Orphan*, Karla L. Gage, S. Alan Walters; Southern Illinois University Carbondale, Carbondale, IL (118)

Pumpkins are an important specialty crop in Illinois and often planted in close geographic proximity to agronomic crops that receive multiple herbicide applications each season. Since the release of dicamba-resistant soybeans and the increased use of dicamba, the impacts of drift on specialty crops has been a growing concern. The objective of this study was to determine the impact of simulated dicamba drift rates applied at two different timings on plant growth and yield on two pumpkin species (Cucurbita pepo var. 'Magic Wand', C. moschata var. 'Autumn Buckskin'). Field studies were conducted in 2019 and 2020 at the Southern Illinois University Horticulture Research Center in Carbondale. The study used a split-split plot design with 4 replications. Simulated drift rates 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. Two applications were made in the month of July approximately one week apart in order for the pumpkins to reach the desired growth stage of 8-leaf and 12-leaf. Qualitative data collection, such as visual ratings, occurred at 7, 14, 21, 28, 42, and 56 days after treatment (DAT) for both applications. Quantitative data on plant growth and yield variables collection occurred at 7, 14, and 21 DAT. Pumpkin growth and yield variables were: vine length, leaf count, adventitious roots, pumpkin weight, average fruit weight, fruit quantity. Qualitative visual ratings were based upon evaluation of chlorosis, necrosis, epinasty, and stunt (data not presented). In the 2019 growing season, application timing influenced growth and yield variables ($P<0.05$) while in the 2020 growing season there was no difference between dicamba application timings. In 2019 simulated drift rates influenced vine length, leaf count, total fruit number ha-1, and total fruit weight ha-1. In the 2020 growing season rates affected leaf count only ($P<0.05$). In 2019, only fruit weight differed ($P<0.05$) between cultivars; whereas the difference between cultivars for average fruit weight and total fruit weight was highly significant ($P<0.0001$) in 2020. These results suggest that yield and growth responses are highly influenced by cultivar. These data also suggest that while simulated dicamba drift rates and timing of a drift event has an effect on pumpkin growth and yield variables, impacts of simulated dicamba drift on growth does not always translate into yield loss.

3MT - 3MT PHD

Flattening the Curve: Using Multiple Tactics to Delay the Spread of Herbicide Resistance.

Lavesta C. Hand*[1], Taylor M. Randell[1], Robert L. Nichols[2], Larry Steckel[3], A Stanley Culpepper[1]; [1]University of Georgia, Tifton, GA, [2]Cotton Incorporated, Cary, NC, [3]University of Tennessee, Jackson, TN (119)

Over the past year as COVID-19 has spread across the globe, science has stressed the need to "flatten the curve" through a multifaceted approach including physical distancing, wearing masks, hand washing, and vaccinations. Although herbicide resistance is certainly not a deadly virus, its impact on the production of food, feed, and fiber is relevant and a similar multifaceted approach to management is needed to preserve farm sustainability. Ways to potentially delay resistance to postemergence (POST) herbicides include the use of cover crops, preemergence (PRE) residual herbicides, and a directed layby application replacing the final topical herbicide application thereby facilitating greater in diversity of mechanisms of action utilized. An experiment was conducted four times during 2018-2019 in GA and TN to evaluate the reduction in Palmer amaranth (*Amaranthus palmeri* S. Wats.) exposure to dicamba POST by these weed management strategies. Treatments were arranged in a split-plot design with the whole-plot comparing conventional tillage to a rolled cereal rye (*Secale cereale* L.) cover crop (biomass of 1,575 to 6,019 kg ha^{-1}). Cotton (*Gossypium hirsutum* L.) was planted in May with row spacings of 92-98 cm placing 2 seeds every 23 cm. The split-plot consisted of four herbicide systems: (1) no herbicide; (2) 3 POST applications of glyphosate (1.12 kg ha^{-1}) + dicamba (0.57 kg ha^{-1}); (3) fomesafen (0.17 kg ha^{-1}) + diuron (0.57 kg ha^{-1}) PRE fb glyphosate + dicamba POST three times; and (4) fomesafen + diuron PRE fb glyphosate + dicamba POST two times fb diuron (0.84 kg ha^{-1}) + MSMA (1.38 kg ha^{-1}) as a directed layby. At plant, POST 1, POST 2 and POST 3 or layby applications were made when cotton was planted, 1-2 leaf, 4-5 leaf, and 8-10 leaf, respectively. To quantify reductions in dicamba exposure associated with cover crops, preemergence herbicides, and layby applications, Palmer amaranth infesting each plot in its entirety was counted 1 day before each POST herbicide application. This allowed for dicamba exposure over the entire season to be calculated for each herbicide and tillage system. Cotton was harvested for yield comparison. In terms of weed control, the cover crop alone provided 75, 70, and 54% control of Palmer amaranth at POST 1, POST 2, and POST 3/layby applications, respectively. PRE applications reduced Palmer amaranth density 99, 99, and 96% at the aforementioned application timings, respectively, in both tillage systems. For the entire season, over 2.1 million Palmer amaranth ha^{-1} were exposed to dicamba when applying 3 sequential applications of dicamba + glyphosate in conventional tillage. Adding a cover crop or PRE herbicides reduced exposure 65% and 98%, respectively. When comparing the PRE fb 3 POST system to the PRE fb 2 POSTs fb layby, a numeric reduction in exposure to dicamba of 68% was noted. Seed cotton yield was 16% higher when including PRE herbicides and 14% higher when planting into a cover crop, demonstrating not only a weed management benefit associated with these practices but yield increases as well.

The Effect of Substrate Stratification and Fertilizer Placement on the Common Liverwort (*Marchantia Polymorpha*) Establishment and Growth of Blue Plumbago (*Plumbago Auriculata*) in Container Nursery Production. Yuvraj Khamare*[1], Stephen C. Marble[2], James Altland[3], Annette Chandler[1]; [1]University of Florida, Apopka, FL, [2]University of Florida - Mid Florida Research and Education Center, Apopka, FL, [3]USDA-ARS, Wooster, OH (120)

Substrate stratification, a method of filling nursery containers with growing media (i.e. pine bark) in "layers" of different physical properties, was investigated as a potential weed management tool. This study evaluated the use of coarse bark (screened to 1.3 or 1.9 cm) as the top substrate and finer bark (0.95 cm) as the bottom substrate with the goal of reducing moisture levels on the container surface to reduce weed germination and growth. The objective of this study was to evaluate the effect of stratified substrates and strategic fertilizer placement on the growth of common nursery weeds and ornamental crops. A total of eight substrate treatments were evaluated using pine bark previously screened to 0.95, 1.3, or 1.9 cm. The stratified substrate treatments consisted of either the 1.3 or 1.9 cm pine bark as the top substrate, applied at depths of either 5 or 7.5 cm with the bottom substrate being comprised of 0.95 cm bark. Industry standard substrate treatments consisted of either 0.95, 1.3, or 1.9 cm pine bark and no stratification. All pots were fertilized at the same rate; however stratified treatments had fertilizer incorporated only within the bottom substrate while industry standard treatments had fertilizer incorporated throughout the substrate profile. Results showed that in all stratified treatments, liverwort coverage decreased by 95% to 99% in comparison with the industry standard treatments. Data also showed no difference in the root or shoot dry weight of blue plumbago when comparing stratified vs. industry standard substrates at 6 months after potting. Overall, results indicate that substrate stratification may be an effective weed management tool, but additional data is needed on more weed and ornamental species.

Allelopathy: Weeds Practicing Social Distancing. Varsha Varsha*[1], Te-Ming (Paul) Tseng[2]; [1]Mississippi State University, Starkville, MS, [2]Mississippi State University, Mississippi State, MS (121)

Sweet potato is an essential commodity in the US with an annual value of $132 million. Its production is the economic and social backbone in rural communities that produce the crop. North Carolina and Mississippi rank numbers one and two, respectively, in sweet potato acreage in the US. The major constraint in sweet potato production is weeds interference. The most troublesome broadleaf weeds in sweet potato production fields are pigweeds. One such pigweed species is Palmer amaranth, which can reduce sweet potato yields by up to 81% with season-long interference. Weed management is a concern among 87% of organic/transitional sweet potato producers. A number of chemical herbicides are currently used to control these weeds, but these herbicides have several adverse effects on our environment, ecosystem, biodiversity, human's health, and results in the development of herbicide resistance in weeds. Because of these reasons, there is a need for an alternative weed management strategy that is effective and economically sustainable. The current study investigates alternative weed management strategies, and allelopathy is one such environment-friendly and safe means of weed control. Allelopathy is the production of chemical compounds by one plant species which inhibits the growth and development of the neighboring plant species. If a crop has strong allelopathic action against various weeds, it can be used as a potential source for controlling weeds with minimum dependency on herbicides. Though allelopathic studies are scarce for sweet potato, some studies have demonstrated that it has significant allelopathic properties, and different varieties exhibit different rates of weed inhibition. A better understanding of allelopathy and the production of allelochemicals will allow us to improve weed-suppressive potential of crops. Furthermore, identification of chemicals/genes involved in weed suppression will provide insight into the mechanism(s) associated with allelopathy. The availability of allelopathic crop varieties will be especially valuable for organic sweet potato producers, and its adaption will ultimately minimize the health risks associated with the herbicides.

Variable Weather and Implications for Herbicides Efficacy and Yield Loss Due to Weeds.
Christopher A. Landau*[1], Adam Davis[1], Patrick Tranel[1], Aaron Hager[1], Nicolas F. Martin[1], Martin Williams[2]; [1]University of Illinois, Urbana, IL, [2]USDA-ARS, Urbana, IL (122)

Midwest agriculture is not immune to climate change, as evidenced by increased greenhouse gas levels, more variable and extreme precipitation, and higher average air temperatures. These trends are expected to worsen throughout the 21st century. Variable weather impacts crops, weeds, and their management; however, empirical study of these phenomena has been piecemeal and limited to a handful of site-years (e.g. generally 2 to 4). This project was developed to shed light on how future climate variability in the Midwest can affect crop and weed management options and outcomes. A meta-analysis was conducted on a database of >3,000 individual herbicide evaluation trials conducted between 1992 and 2019. We quantified rainfall and temperature variation on the efficacy of several common preemergence herbicides used individually and in combination on key Midwest weed species. Our results demonstrated a rainfall threshold of 5–10 cm within 15 days of application of specific herbicides was required to maximize the probability of acceptable control of the weeds studied. We also examined linkages among weather, crop management, and weed control on crop yield. We found that late-season weed control was the largest contributer to yield loss in corn and soybean. Furthermore, inadequate water availability and excessive temperatures during silking in corn, or during seed filling in soybean, exacerbated yield loss from poorly controlled weeds. Current trajectories portend a future with weed control becoming more difficult, driven in part by herbicide resistance, and weather becoming more variable, driven by climate change. Adapting Midwest corn and soybean production for the future requires considering the significance of weeds and transforming how they are managed.

Residual Activity of Glyphosate Damages Transplant Squash But Can be Influenced by Tillage and Irrigation. Taylor M. Randell*[1], Jenna C. Vance[1], Lavesta C. Hand[1], Hannah E. Wright[2], A Stanley Culpepper[1]; [1]University of Georgia, Tifton, GA, [2]University of Georgia, Athens, GA (123)

Annual fresh-market squash (Cucurbita pepo L.) production in Georgia is an estimated $40 million industry, up 60% in value over the last 5 years. With limited weed management options available in squash, glyphosate is a critical tool to help remove weeds before planting, and provides growers the opportunity to plant into weed-free fields. Recently published research, however, suggests that glyphosate applied preplant can injure cucurbit transplants when applied on soils with low organic matter and high sand content. Thus, two experiments were conducted from 2018 through 2020 to determine the tolerance of transplanted squash to glyphosate applied preplant, and to determine if implementing cultural practices could mitigate injury. Experiment one, conducted at two locations, included glyphosate (0, 1.54, 3.08, 4.62 kg ai ha^{-1}) applied 7, 4, or 1 d before transplanting squash into a non-mulched (bareground) system. The factorial combination of treatments were arranged in a randomized complete block design and included four replications. Combined across 2018-2019, significant interactions between application interval and glyphosate rate were observed for crop injury and biomass; yield was only impacted by main effects. Assessments indicated that glyphosate preplant applied at the two highest rates 7, 4, or 1 d before planting (DBP) injured squash 11 to 53% and reduced early-season biomass up to 80%. Glyphosate at 1.54 kg ha^{-1} did not influence squash growth when applied 7 or 4 DBP, but caused a maximum of 13% injury with a 24% reduction in biomass when applied 1 DBP. After harvesting squash 30 times, the two highest rates reduced fruit number and fruit weights 29 to 53%; the lowest rate of glyphosate did not influence yield across plant-back intervals. Experiment two, included glyphosate (0, 3.08, 6.17 kg ai ha^{-1}) applied preplant 1 DBP, followed on the same day by 1) overhead irrigation of 0.5 cm, 2) light tillage with a rototiller, 3) irrigation plus tillage, or 4) no tillage or irrigation. Factorial treatment combinations were arranged in a randomized complete block design, including four replications in 2020. Significant interactions between glyphosate rate and tillage for crop injury and biomass were observed, with both main effects only impacting squash yield; irrigation did not influence squash response. Glyphosate injured squash 12 to 38% and reduced early-season biomass 45%; with the addition of tillage, injury was less than 5% and early-season growth was similar to the control. Irrigation did not alleviate visual injury or biomass losses from glyphosate. After harvesting squash 30 times, early-season (harvest 1-8) yield loss was 43 to 49%. Tillage eliminated the negative impact from glyphosate on yield, while irrigation alone was not beneficial. Although irrigation was not beneficial alleviating damage from glyphosate in this study, previous research has shown benefits when at least 1 cm of irrigation is implemented after application, but before transplanting cucumber. Thus, additional research better understanding the influence of irrigation volume on transplant injury from glyphosate preplant is warranted.

The Effect of Florpyrauxifen-benzyl and Other Pasture Herbicides on Sward Composition.

Wykle C. Greene*, Michael L. Flessner, Kevin W. Bamber, Matthew P. Spoth, Cynthia Sias; Virginia Tech, Blacksburg, VA (124)

Effective weed control in pastures and hayfields is critical for maximizing overall forage production. A key limitation in the willingness of producers to apply herbicides is the risk of killing forage legumes. There are currently no labeled herbicides which control broadleaf weeds while preserving white clover (*Trifolium repens.* L.). Florpyrauxifen-benzyl is an auxin herbicide which is contained in products ProClova and DuraCor with 2,4-D and aminopyralid, respectively. ProClova is reported to preserve established white clover. Studies were conducted across two locations in Virginia in 2020 to determine the effect of these new herbicide combinations, as well as other commonly used pasture herbicides on sward composition. Herbicide treatments consisted of 1) florpyrauxifen-benzyl + 2,4-D, (2) florpyrauxifen-benzyl + aminopyralid, (3) 2,4-D + aminopyralid, (4) 2,4-D + dicamba, and (5) metsulfuron. Herbicides were applied to established cool-season grass pastures containing white clover and assorted weed species. A randomized complete block design with four replications was utilized. Biomass and species composition data for forage, legume, weedy grasses, and broadleaf weed species were taken (via 0.5m^2 subplots and line-intercept methods, respectively) twice throughout the growing season, mimicking hay production. There were no differences between herbicides for early season forage grass biomass production. All herbicides resulted in greater late season forage grass production compared to the nontreated control with florpyrauxifen-benzyl + 2,4-D producing the highest amount of forage grass biomass (3292 kg ha^{-1}). Between herbicide treatments legume production was greatest with florpyrauxifen-benzyl + 2,4-D resulting in 267 kg ha^{-1}, while all other herbicide treatments eliminated legumes, while the nontreated control resulted in 639 kg ha^{-1}. All herbicide applications significantly reduced broadleaf weed biomass with the exception of metsulfuron. Species composition data largely corroborated biomass findings. This research indicates that florpyrauxifen-benzyl + 2,4-D is a viable option to control broadleaf weed species while preserving high amounts of white clover and all other herbicide treatments are effective at controlling broadleaf weeds, leading to an increase in forage grass.

The Effects of Cereal Rye (*Secale cereale*) Seeding Rate and Termination Timing on Weed Control and Soybean Yield. Alyssa Essman*, Mark Loux, Anthony Dobbels, Alexander Lindsey; The Ohio State University, Columbus, OH (125)

There has been increased interest in cover crops in recent years due in part to their potential role in the integrated management of herbicide-resistant weeds. Growers have been experimenting with different cover crop termination timings in an attempt to maximize 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 timing 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.

Can We Improve Detection Methods for Herbicide Residues in Plants? Hannah E. Wright*[1], John Shugart[2], Carrie Crabtree[2], Taylor M. Randell[3], Lavesta C. Hand[3], A Stanley Culpepper[3]; [1]University of Georgia, Athens, GA, [2]Georgia Department of Agriculture, Tifton, GA, [3]University of Georgia, Tifton, GA (126)

Herbicide drift threatens the sustainability of critical weed management tools, not only by potentially severely injuring crops, but by further increasing the negative public perception of pesticides. When herbicides move off-target it is critical to correctly identify the source. For most states, including Georgia, the state lead agency such as the Georgia Department of Agriculture (GDA), is often tasked with collecting plant samples for residue analysis. These agencies often depend on residue detections to confirm drift. Two field experiments were conducted during 2020 to help the GDA improve their ability to detect herbicides in plants through improving sampling techniques. Treatment design was a randomized complete block with 4 replications. A nontreated control was included for each sampling method. Low-dose rates of 1/1,000X and 1/250X of the standard field use rates for dicamba (0.56 kg ae ha^{-1}) and 2,4-D (1.07 kg ae ha^{-1}) were applied over 9-leaf non-tolerant cotton (*Gossypium hirsutum* L.) to evaluate injury, plant height, yield, and herbicide residues. Two plant collection methods (whole plant or new growth after treatment) and interval between application and plant collection (7 and 21 days after application (DAA)) were compared. For plant residue analysis, samples were taken to the GDA pesticide laboratory for sample preparation and analysis. Data were subjected to ANOVA in JMP v14.1 and means were separated using Tukey's HSD where applicable. Maximum injury from dicamba was 10% at the 1/250 rate 23 DAA; no visual injury was detected at the lower rate. Dicamba did not influence plant growth or yield. Laboratory analysis detected residues of dicamba of 0.005 ppmv from the 1/1000 rate application and 0.016 ppmv at the 1/250 rate but only when samples were taken 7 DAA; plant sampling technique did not influence detection levels. For 2,4-D, injury was 31 and 71% for the 1/1,000 and 1/250 rates, respectively. Though visual injury was severe, there were no reductions in plant height. Seed cotton yield was reduced 10 and 57% by the 1/1,000 and 1/250 rates, respectively, when compared to the control. Residue levels recorded were 0.02 PPM from the 1/1000 rate application and 0.06 PPM at the 1/250 rate but only when samples were taken 7 DAA. Similar to dicamba, 2,4-D laboratory detection did not occur with samples taken 21 DAA and sampling technique did not influence results. Experimental results suggest that the time interval between drift and sampling is more important than the rate of herbicide drift or plant sampling technique when analyzing for 2,4-D or dicamba residues.

Seasonal Herbicide Efficacy for Smutgrass (*Sporobolus indicus*) Control in Improved Pastures in Texas. Zachary S. Howard*[1], Mason T. House[1], Matthew Matocha[2], Scott A. Nolte[3]; [1]Texas A&M University, College Station, TX, [2]Texas A&M AgriLife Extension Service, College Station, TX, [3]Texas A&M AgriLife Extension, College Station, TX (127)

From Pest to Pal: Discovering Stress Tolerant Weedy Rice. Shandrea D. Stallworth*[1], Swati Shrestha[1], Brooklyn C. Schumaker[2], Nilda Roma-Burgos[3], Te-Ming (Paul) Tseng[1]; [1]Mississippi State University, Mississippi State, MS, [2]Mississippi State University, Starkville, MS, [3]University of Arkansas, Fayetteville, AR (128)

Rice (*Oryza sativa*) is a primary food source for more than one-third of the world's population. To continue to provide for the growing population, rice production must increase by more than 70% over the next ten years. This task can prove difficult due to the consistent, negative impacts of climate change. Rice yields continue to decline under continuing stressors such as cold and heat. Cold temperatures below 17°C can reduce yield from 10 – 100%, while temperatures above 34°C can cause spikelet infertility leading to upwards of 60% yield reduction. Current rice-breeding programs lack the necessary genetic diversity to protect rice against these stressors, and potentially useful genes have been lost through domestication. To overcome this loss of genes, it is possible that a close, weedy relative of rice could be vital in rediscovering these lost traits. Weedy rice (WR), *Oryza sativa* ssp., is a noxious subspecies genetically similar to rice, with proven competitive ability within rice fields. Current phenotypic studies have identified abiotic stress-tolerant weedy rice lines, but further research is needed to identify the genetic mechanisms associated with this increased competitiveness. Using a standard panel of rice SSR markers, hierarchal clusters, and neighbor-joining trees, the relationship between rice and WR was studied. SSR markers successfully identified unique clusters among cold and heat-sensitive cultivated rice and tolerant WR lines. Additionally, an average of four (4) SSR markers with 100% probability were found to be associated with cold and heat-tolerant and sensitive rice and WR lines. These SSR markers were also linked to rice QTLs associated with cold tolerance in sensitive WR lines and plant height in heat-stress tolerant WR lines. These SSR markers can be used in the future to identify genes associated with stress tolerance in O. sativa.

Utility of Potassium Tetraborate Tetrahydrate as a Dicamba Volatility Reduction Agent.
Mason C. Castner*, Jason K. Norsworthy, Trenton L. Roberts, Maria Leticia M. Zaccaro; University of Arkansas, Fayetteville, AR (129)

The *N,N*-bis(3-aminopropyl)methylamine (BAPMA) salt of dicamba (Engenia) and diglycolamine salt of dicamba with VaporGrip (XtendiMax) are labeled for preemergence and postemergence control of broadleaf weeds in dicamba-resistant cropping systems. In-crop applications of dicamba have resulted in a record number of complaints regarding off-target movement of the herbicide since introduction of the technology in 2017. To reduce dicamba volatility, the University of Arkansas Division of Agriculture has pursued potassium tetraborate tetrahydrate as a tank-additive (potassium borate) based on its ion scavenging, buffering, and nutritional potential. Both small- and large-scale volatility studies were conducted to investigate the impact of this additive on dicamba. For low-tunnel evaluation, the diglycolamine (DGA) salt of dicamba plus potassium salt of glyphosate was applied in mixture with potassium borate at six molar concentrations (0, 0.00625, 0.0125, 0.025, 0.05, and 0.1 M) delivered at 140 L ha^{-1} to two moist flats placed under each tunnel. Treated flats, high-volume air samplers, and low-tunnels were removed from the field 48 hours after application. As potassium borate concentration increased beyond 0.00625 M (0.0125 to 0.1 M), dicamba volatility decreased compared to DGA dicamba plus glyphosate with no additive for each of the three evaluated parameters of maximum soybean injury (20- to 36- percentage points), average injury, and distance traveled (1.5- to 3.4- m). Air sample data closely aligned with the evaluated parameters. Overall, the addition of potassium borate to dicamba has great potential in reducing dicamba volatilization while offering producers an opportunity to alleviate boron deficiencies.

Optimization of Glufosinate Efficacy in Low-light Conditions. Grant L. Priess*, Jason K. Norsworthy, Maria Leticia M. Zaccaro, Mason C. Castner, Rodger B. Farr; University of Arkansas, Fayetteville, AR (130)

The incorporation of glufosinate-resistance into XtendFlex, Enlist, and LibertyLink crops has increased glufosinate use and subsequent selection pressure on troublesome weed species. One weakness of glufosinate is the decrease in efficacy that is observed when applications are made in low-humidity and low-light intense environments. To overcome the impact that light-intensity has on glufosinate efficacy field experiments were conducted in 2019 and 2020, in Fayetteville, AR. The experiments were designed to evaluate the utility of mixing a broad-spectrum glutathione *s*-transferase inhibitor with glufosinate to improve efficacy of monocot and dicot weed species while maintaining adequate glufosinate-resistant-crop tolerance. When applications of glufosinate (667 g ai ha^{-1}) plus the GST inhibitor (270 g ai ha^{-1}) were applied at 10pm Palmer amaranth and large crabgrass control improved 26- and 36-percenatage points, respectively, when compared to glufosinate (667 g ai ha^{-1}) alone at 10pm. Additionally, when glufosinate plus 0 to 1076 g ai ha^{-1} of the metabolic inhibitor was applied at 10am or 10pm less than 5% injury of XtendFlex and Enlist cotton, LLGT27 soybean, and LibertyLink corn was observed. Thus, mixing the GST inhibitor and glufosinate improved weed control in low-light environments and did not significantly impact crop tolerance. With increased glufosinate use and the subsequent selection pressure placed on weed population the addition of metabolic inhibitors to glufosinate may alleviate variability in efficacy and mitigate selection for herbicide-resistant biotypes.

Aspects of Growth and Development of Female and Male Palmer Amaranth (*Amaranthus palmeri*). Ednaldo A. Borgato*, Mithila Jugulam, Anita Dille; Kansas State University, Manhattan, KS (131)

Palmer amaranth (*Amaranthus palmeri*) is a dioecious and the most troublesome weed in the US and many populations have evolved resistance to multiple herbicide sites of action. For the success and sustainability of weed control in a long-term, strategies that impede emergence and seed production are recommend. Understanding biological characteristics can optimize the adoption of such practices in weaker stages of a weeds' life-cycle. The objective of this research was to investigate differences in the phenology of female and male plants of Plamer amaranth that could be incorporated as a management decision tool. A greenhouse experiment was performed using the destructive method to study growth and development aspects of female versus male plants. Plant height (cm), days to flowering (d), days to anthesis (d) and the length of the inflorescence on the main stem (cm) through time were measured. Height, days to flowering and to anthesis were evaluated using Mann-Whitney U Test to compare measurements across gender. Additionally, a linear regression was performed to analyze the inflorescence length, also comparing both genders. Palmer amaranth height was not significant between male or female plants. However, male plants showed emergence of the inflorescence ahead of females. Nonetheless, the female plants had the pistils emerged before the anthesis of male plants. Interestingly, linear regression analysis showed that the length of male inflorescence was stable through time, with a slope not differing from zero, whereas, female plants continued to increase the size of the inflorescence. Data suggested that anthesis pattern, with pistils exposed before pollination, indicate an adaptation that favors fertility. Moreover, the increment in female inflorescence length through time suggests an indeterminate flowering aspect that contributes to prolificity. Management decisions could incorporate knowledge of reproductive differences of female *versus* male to reduce seed production. Future research will investigate photoassimilate partitioning of female and male Palmer amaranth through time to model the growth of female and male plants.

Evaluation of Multi-tactic Weed Management Strategies to Target Palmer Amaranth in Cotton. Sarah E. Kezar*[1], Delaney C. Foster[2], Michael M. Houston[3], Peter A. Dotray[4], Jason K. Norsworthy[3], Ramon G. Leon[5], Gaylon Morgan[6], Muthukumar V. Bagavathiannan[1], Fernando Oreja[5]; [1]Texas A&M University, College Station, TX, [2]Texas Tech University, Lubbock, TX, [3]University of Arkansas, Fayetteville, AR, [4]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX, [5]North Carolina State University, Raleigh, NC, [6]Cotton Incorporated, Cary, NC (132)

Palmer amaranth is a major weed throughout the US Cotton Belt, and minimizing seedbank inputs from uncontrolled weed escapes during the cropping season as well as post-harvest recruits is of paramount importance for impacting long-term species persistence. To understand the impact of various management tactics on the occurrence of Palmer amaranth escapes and overall seedbank addition potential, a multi-state study is being carried out in four locations (Raleigh, NC; Keiser, AR; Lubbock, TX; and College Station, TX), representing key environments in the US Cotton Belt. XtendFlex® cotton was planted in a Randomized Complete Block Design with four replications, and the crop was managed using standard production practices specific to each region. With respect to weed management, a number of tactics were evaluated, including the use of cover crops, PRE herbicides, POST residuals, layby application, and late-season treatments targeting weed seed viability with the use of a dual-purpose harvest aid. Additionally, a precision-application treatment was included to target escapes prior to reproduction. Soil seedbank, seedling emergence pattern, aboveground densities, phenological development, seed production, and cotton yield were documented. Preliminary results showed that integrated management programs significantly impacted the number of Palmer amaranth escapes, phenology, and seed production, though cotton yields were not influenced within the first year of this study. There were considerable variabilities among the locations for these variables, but the value of a multi-tactic strategy was consistently evident compared to the standard management program. Studies are ongoing to understand the impact of these treatments on weed seed viability and seedling vigor. The experiments will be continued over the next three years to elucidate long-term impact of these treatments on Palmer amaranth population dynamics and cotton yield. Results are expected to guide the development of robust integrated management programs for Palmer amaranth in cotton.

Could Epigenetics Help to Understand Herbicide Resistance in Weeds? Gourav Sharma*, Jacob Barney, Shawn Askew, James Westwood, David C. Haak; Virginia Tech, Blacksburg, VA (133)

Shattercane [*Sorghum bicolor (L.) Moench nothosubsp. drummondii* (Nees ex Steud.) de Wet ex Davidse] is one of the weedy subspecies of S. bicolor, being a troublesome agricultural weed in the United States for at least 150 years. Shattercane is primarily controlled by pre-emergence and post-emergence herbicides in agricultural fields. Unfortunately, over-reliance on herbicides has led to the evolution of herbicide resistance through target site (TSR) and non-target site resistance (NTSR) mechanism (NTSR). However, we know the genetics behind the TSR mechanism but we lack a proper understanding of the NTSR mechanism. It has been suggested that epigenetic processes, such as DNA methylation, histone modifications, and smRNA regulation could be contributing to the genetic basis of non-target site resistance mechanism. To understand the role of DNA methylation we administered sub-lethal doses of glyphosate, trifloxysulfuron, clipping, and shading to determine if methylome changes are shared or unique among stress responses. Methylation occurs in all cytosine sequence contexts of plant DNA: CG, CHG, and CHH (H represents A, T, or C). The tissues from control and stressed plants were collected at standardized maturation levels and subjected to whole-genome, bisulfite sequencing (WGBS). We found that the highest levels of methylation in CG (20.5%) context followed by CHG (7.5%) and CHH (4.8%) context. Our results are in accordance with previous studies and indicate that methylation at promoter sites (CpG islands) are crucial for stress adaptations. DNA hypomethylation refers to the loss of the methyl group in the 5-methylcytosine nucleotide, whereas hypermethylation refers to the addition of the methyl group. The gain and loss of the methyl group can change gene expression. Glyphosate and shade stressed plants showed hypermethylation at transposable and repeat elements. Whereas hypomethylation in glyphosate stressed plants was recorded at promoter and genic regions. These results indicated that DNA methylation patterns are non-random and unique for each stress response. Further analyses will elucidate how the location of methylation in the genome aids in stress adaptation.

Controlling Palmer Amaranth: A Growing Threat to US Cotton Production Systems.

Rohith Vulchi*[1], Muthukumar V. Bagavathiannan[1], Joshua A. McGinty[2], Scott A. Nolte[3]; [1]Texas A&M University, College Station, TX, [2]Texas A&M AgriLife Extension, Corpus Christi, TX, [3]Texas A&M AgriLife Extension, College Station, TX (134)

Field trials were conducted during 2019 and 2020 in irrigated (College Station) and dryland (Thrall) locations in Texas to determine the influence of tillage, crop rotation and herbicide programs on weed management. High Input herbicide program (HI) with residual herbicides was compared against Low Input herbicide program (LI) without residual herbicides in Cover cropping, Strip till and Conventional till practices under cotton-cotton and cotton-sorghum rotation schedules for their efficacy on Palmer amaranth (AMAPA) control. A weedy check and weed free check were also maintained alongside for comparison purposes. During 2019 at both locations, HI herbicide program in cover cropping and conventional tillage provided not less than 92% and 95% AMAPA control, respectively, throughout the cropping season. During 2020 at College Station, conventional tillage provided more than 95% AMAPA control whereas AMAPA control in cover crop was 80-85%, which was significantly lower compared to 2019. However, at Thrall, cover crop and conventional tillage provided not less than 90% AMAPA control throughout the cropping season. During 2020, cover crop biomass at College Station was approximately 2200 kg/ha for both HI and LI treatments, whereas at Thrall, it ranged from 4000-6000 kg/ha. HI treatments reduced the AMAPA density early in the season by more than 50% compared to LI treatments. Conventional till and cover crop had the lowest and highest AMAPA density, respectively. Risk simulation models using the net returns of each treatment over the two years indicate risk averse growers see greater benefit from conventional tillage whereas areas with greater available soil moisture or access to irrigation would see more advantages from a cover crop-based system.

Using Living Mulch in Reduced Tillage Organic Soybeans. Veronica Yurchak*, Cerruti R. Hooks; University of Maryland, College Park, MD (135)

Soybean production systems typically incorporate tillage and/or herbicides to control weeds, however frequent tillage can reduce soil health and selection for herbicide resistant weed populations necessitates alternative strategies for weed control. Organic mulch from dead cover crop biomass provides a possible strategy for controlling weeds by suppressing annual weed germination. However, residue from killed cover crops decomposes over the growing season, and rarely can provide season-long suppression of weed growth. Alternatively, perennial cover crop species can work like a living mulch and actively compete with weeds the entire growing season, however competition between the living mulch and the crop must be minimized. This experiment is a continuation of a previous study investigating the use of novel cover crop residue + living mulch combinations in sweet corn. In this experiment, we tested the ability of three annual cover crop species (cereal rye *Secale cereale*, forage radish *Raphanus sativus var. longipennatus* and crimson clover *Trifolium incarnatum*) and a perennial red clover (*Trifolium pratense*) living mulch to reseed or return and suppress weeds through the soybean critical weed free period. Results of this study show successful reseeding and establishment of some cover crop species. Weed biomass accumulation at the end of the critical weed free period was significantly less in all cover crop treatments compared to a conventionally tilled control treatment. Additionally, living mulch treatments yielded similar to the standard conventional till treatment, indicating competition with the living mulch did not result in a yield reduction. Initial results of the first year of this study show that reseeded/returning cover crop and living mulch treatments suppressed weeds effectively and may serve as a potential tool for non-chemical weed suppression in soybean systems. However, limitations to this technique include the need for specialized strip-tillage equipment, as well as potential impediments to crop harvest.

Assessing Genetic Diversity in Weed-suppressive Cotton Chromosome Substitution Lines.
Worlanyo Segbefia*[1], Grace Fuller[1], Sukumar Saha[1], Te-Ming (Paul) Tseng[2]; [1]Mississippi State University, Starkville, MS, [2]Mississippi State University, Mississippi State, MS (136)

Cotton production faces a constant threat of weed interference. Not only do these weeds increase production costs, but they also reduce fiber quality and serve as the breeding grounds for plant diseases. Weeds account for about 34% of yield losses. In Mississippi, Palmer amaranth (*Amaranthus palmeri*) has been identified as the most common and troublesome cottonweed. The absence of crop/farm rotation and the continuous application of a particular herbicide has resulted in weeds developing herbicide resistance over time. Palmer amaranth has proven to be resistant to glyphosate and other herbicides; therefore, there is a need to supplement chemical weed control strategies. Allelopathy, a promising weed control technique, uses secondary metabolites from a plant species to inhibit the growth and development of plants nearby. This project uses backcrossed chromosome substitution (CS) lines developed with a homologous pair of chromosome or chromosome arm of *G. barbadense* (CS-B), *G. tomentosum* (CS-T), and *G. mustellinum* (CS-M), substituted for homologous pair of *G. hirsutum* (TM-1) chromosome or chromosome arm, to screen for weed-suppressive ability. From the 50 CS lines, eight were tested in greenhouse assays to assess the extent of Palmer amaranth suppression. Four CS lines (CS-B01, CS-B18, CSOB16, and MNTN-4-15) were able to inhibit the growth of Palmer amaranth by reducing its height and root length by up to 60 and 40%, respectively. Height reduction was highest for BNTN 16-15 (mean value of 82) and lowest for Enlist (approximate mean value of 18). Besides, chlorophyll reduction was highest for BNTN 16-15, with a mean value of 65, and lowest for Enlist, with a mean value of 2. Additional CS lines will be screened and compared. From the greenhouse screening, 20 best cotton CS lines (per highest weed suppressive ability), and a commonly grown Upland cotton cultivar in Mississippi will be selected for future field bioassays using Palmer amaranth.

Antagonizing Effects of Dicamba Tank Mixes in Controlling *Echinochloa*. Clay M. Perkins*[1], Larry Steckel[1], Thomas C. Mueller[2]; [1]University of Tennessee, Jackson, TN, [2]University of Tennessee, Knoxville, TN (137)

Junglerice (*Echinochloa colona* (L.) has become a major weed in the Mid-south US and other areas. Glyphosate resistance has been documented on junglerice populations and is part of the reason for the increase in prevalence. However, poor junglerice control from glyphosate + dicamba tank mixes is observed in many fields where glyphosate resistance is not occurring. Glyphosate + dicamba application is applied on the majority of these row crop areas in Tennessee. Therefore, research was conducted assessing reduced grass control with glyphosate when applied with dicamba. This field experiment was replicated across three locations and two years for a total of six experiments. The research was arranged in a factorial design with nozzle selection and herbicide treatment being the factors. TTI nozzles and AIXR flat fan nozzles were tested in this experiment. The second factor was herbicide treatment included a non-treated (check), glyphosate (Roundup, Bayer Crop Protection, St. Louis, MO), clethodim (Intensity, Loveland Products, Greenville, MS), glyphosate + clethodim, glyphosate + dicamba (Engenia, BASF Corporation, Ludwigshafen, Germany), clethodim + dicamba, glyphosate + clethodim + dicamba, glyphosate + dicamba + DRA (OnTarget, Winfield United, Arden Hills, MN) and clethodim + dicamba + DRA. Herbicide rates were consistent throughout with glyphosate at 870 g ha^{-1}, dicamba at 560 g ha^{-1}, and clethodim at 105 g ha^{-1}. DRA was used at 0.25% v/v. Applications were made with a CO_2 backpack sprayer calibrated to apply 142 L ha^{-1} of water carrier. Each herbicide treatment was evaluated using each nozzle previously mentioned. Applications were made when junglerice plants were 8-10 cm in height. Control of junglerice was visually assessed on a scale of 0 to 100% where 0 = no injury and 100 = plant death at 7, 14, and 21 days after treatment. Dicamba tank mixes decreased junglerice control from clethodim and glyphosate. This data suggests that tank mixes with dicamba results in 15% less junglerice control. An additional 7% control loss is observed from the TTI nozzles, and an additional 16% from adding a DRA to the tank. Moving forward, this data suggests separating glyphosate and/or clethodim applications with dicamba by a couple of days. Data shows that on average, 40% of the fields in Tennessee have both Palmer amaranth plus *Echinochloa* spp. Growers want to control all weeds with one application of glyphosate + dicamba. However, these data show that the addition of dicamba with glyphosate applied with labeled nozzles and DRA is resulting in reduced junglerice control.

Influence of Environment and Soybean Trait Adoption on Dicamba Concentrations in Rainwater and Air Deposits in Missouri. Eric G. Oseland*, Mandy Bish, Kevin W. Bradley; University of Missouri, Columbia, MO (138)

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 and 2020. 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 (2019 R^2=.87; 2020 R^2=.88). Stepwise regression analysis indicated that higher dicamba concentrations were detected in areas where wind speeds during the middle of the day were lower, when a greater duration of the week with inverted temperature conditions, and higher weekly relative humidity. 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.

Shedding Light on the Power of Plant Competition. Nicole Berardi*, Clarence Swanton; University of Guelph, Guelph, ON, Canada (139)

Changes in light quality induced by the presence of neighboring weeds are an important mechanism of plant competition affecting crop plants during the early stages of seedling development. Alteration of the light environment is recognized via changes in the red/far-red light ratio (R/FR), in which a reduction in R/FR is induced by light that is reflected upwards off weeds. Recognition of a reduced R/FR elicits physiological stress responses within the crop plant characterized by increased reactive oxygen species (ROS) production and subsequent modification of antioxidant capacity to regulate ROS levels. The resulting physiological responses due to the presence of neighboring weeds are hypothesized to be the cause of significant yield losses during early season weed competition. To explore the associated stress and antioxidant responses to weed competition, *Arabidopsis* and maize were studied under three light environments, a high R/FR (weed-free, ~1.8) environment, and two low R/FR environments (biologically weedy and artificial FR, ~0.3). Results indicate that in response to the low R/FR light environments levels of ascorbate were significantly decreased when compared with the weed-free light environment in both *Arabidopsis* and maize. Fluctuations in associated antioxidant regenerating enzymes were also observed in both species. These results demonstrate the importance of elucidating the molecular basis of weed-crop competition. Further identification of these responses and associated genes would not only provide important insights into the molecular basis of weed-crop competition but may also provide targets for improving weed stress tolerance in crop plants.

Maximizing Cotton Defoliation Efficacy. Jacob P. McNeal*[1], Darrin M. Dodds[1], Brian K. Pieralisi[2], Greg Kruger[3], Bradley J. Norris[1], John J. Williams[1], William J. Rutland[4], Steven D. Hall[4]; [1]Mississippi State University, Mississippi State, MS, [2]Mississippi State University, Stoneville, MS, [3]University of Nebraska - Lincoln, North Platte, NE, [4]Mississippi State University, Starkville, MS (140)

From 2018 - 2020, a field experiment was conducted to evaluate the effect of carrier volume and spray droplet size on the efficacy of cotton (*Gossypium hirsutum*) defoliation programs. This experiment was conducted at the R.R. Foil Plant Science and Research Center in Starkville, Mississippi and at the Black Belt Branch and Experiment Station in Brooksville, Mississippi. Eight-row (7.7m x 12.1m) plots were planted to DP 1646 B2XF. Initial harvest aid applications were made at 60% open boll, and secondary applications to select plots occurred 12 days later. Applications were made with a Capstan® Pinpoint Pulse-Width Modulation (PWM) sprayer on a high-clearance Bowman Mudmaster at a speed of 14.5 km $hour^{-1}$. This experiment utilized two carrier volumes: 47 and 187 L ha^{-1}, and three droplet sizes: 200 µm, 500 µm, and 800 µm. Defoliation materials included: thidiazuron (TakeDown® SC) applied at 0.15 kg ha^{-1}, ethephon (BollBuster®) applied at 1.5 kg ha^{-1}, tribufos (Folex® 6EC) applied at 0.37 kg ha^{-1}, and pyraflufen-ethyl (ET®) applied at 0.105 kg ha^{-1}. Defoliation programs included: [1A] thidiazuron + ethephon and [1B] thidiazuron + ethephon + tribufos, [2A] 1A + pyraflufen-ethyl + ethephon, and [2B] 1B + pyraflufen-ethyl + ethephon. Visual ratings were taken at 3, 7, and 10 days after application (DAT) for both A and B applications, and included open bolls, green leaves, defoliation, desiccation, and terminal regrowth and basal regrowth. All ratings were normalized to the non-treated control. The center two rows were mechanically using a spindle picker modified for plot research, and seed cotton samples for each plot (4.5 kg) were sent to the University of Tennessee in Jackson, TN for ginning. Fiber quality was determined by the USA classing office in Memphis, TN. The experimental design was a factorial arrangement of treatments within a randomized complete block and included four replications, each with a non-treated control. Data were analyzed in SAS v. 9.4 using PROC MIXED. Means were separated using Fisher's Protected LSD at an alpha level of 0.05. Results did not vary across year or location, and were therefore pooled across these factors. No affect was observed on seedcotton yield or fiber quality, and, therefore, our conclusions are based solely on defoliation efficacy. We conclude that cotton defoliation efficacy to be positively and negatively correlated with carrier volume and spray droplet size, respectively. Additionally, independent of all other factors evaluated in this study, we observed a secondary application of pyraflufen-ethyl + ethephon + crop oil to significantly improve defoliation efficacy over single applications alone. Finally, correlation analyses revealed that maximum defoliation efficacy occurred from secondary applications to plots with apparently sub-optimal defoliation following the first application. As such, we conclude that maximum defoliation efficacy is achieved from cotton defoliation programs consisting of two-applications, each consisting of high carrier volumes and fine spray droplet sizes. However, for maximum profitability and ROI, we conclude that lower carrier volumes have utility in cotton defoliation programs to substantially reduce all input costs associated with defoliation applications, thereby maximizing efficiency, profitability, and economic ROI.

Many Little Hammers to Manage Herbicide-Resistant Waterhemp (*Amaranthus tuberculatus*) in Iowa Corn and Soybean. Ramawatar Yadav*, Prashant Jha, Avery J. Bennett, Ryan Hamberg, Alexis L. Meadows, Edward Steven Dearden; Iowa State University, Ames, IA (141)

Common waterhemp (*Amaranthus tuberculatus*) 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, multi-tactic strategies ("many little hammers") 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 sites-of-action herbicides), aggressive (three sites-of-action herbicides), and aggressive 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}. 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 for an effective and diversified weed control program in corn to reduce weed seed inputs in the following soybean crop. Sub-subplots with AHP plus weed seed removal, presence of cover crop, and 38-cm rows (four-hammer approach) reduced waterhemp density and seed production by >85% compared with plots that had MHP, no cover crop, and 76-cm soybean rows (one-hammer approach). More than 90% of the waterhemp seeds that survived the four-hammer approach were destroyed (non-viable) by a fifth-hammer (Redekop™ Seed Destructor) at soybean harvest. These results indicate that multi-tactic strategies targeting waterhemp at different life-stages should be utilized to reduce burden on herbicides-only tactic; hence minimizing the development of herbicide resistance.

Accessing Genetic Diversity in Cotton Chromosomal Substitution Lines Tolerant to Sublethal Rate of 2,4-D Using Molecular Markers. Josiane C. Argenta*[1], Te-Ming (Paul) Tseng[2]; [1]Mississippi State University, Starkville, MS, [2]Mississippi State University, Mississippi State, MS (142)

Cotton is the most important fiber crop grown worldwide. The United States is the third biggest producer of cotton, having a market value of 7 billion dollars. One of the major challenges in the cotton fields is the presence of resistant weed species that compete with the crop for light, water, and nutrients while reducing cotton yield and fiber quality. To manage herbicide resistance in weed species, companies have developed cotton tolerant to herbicide application. However, the drift caused by the off-site movement of sub-lethal doses of 2,4-D to adjacent areas, where susceptible cultivars and other plant species are grown, is of extreme concern in agriculture. The use of chromosome substitution lines (CS lines), which are non-transgenic lines, can be a significant tool for managing the off-target 2,4-D drift. These CS lines inherit the genetic diversity from different tetraploid cotton species (*Gossypium* spp.) that have been lost in the cultivated cotton varieties due to traditional breeding techniques. Therefore, the main goal of this research is to determine the genetic diversity among different CS lines, and between CS lines and cultivated cotton varieties, by using simple-sequence repeats (SSR markers) and further identify genes that can confer tolerance to sub-lethal rates of 2,4-D drift. The results obtained from this research will help cotton breeding programs in developing non-transgenic varieties tolerant to sub-lethal rates of 2,4-D.

Quantifying Pesticide Concentrations Using a Simulated Vegetable Bed. Kayla M. Eason*[1], Timothy L. Grey[1], A Stanley Culpepper[1], Nicholas L. Hurdle[2], Juliana de Souza Rodrigues[1]; [1]University of Georgia, Tifton, GA, [2]University of Georgia, Collierville, TN (143)

Plastic mulch systems utilize low density polyethylene (LDPE) or totally impermeable films (TIF) stretched over tilled soils that have been formed into raised beds. Florida and Georgia produce thousands of hectares of tomato, cucumbers, squash, and other vegetables using this system. Producers often utilize the same plastic mulch for two to five crop production cycles over the course of multiple growing seasons, allowing growers to spread the cost of production over multiple crops and mitigating the cost of reapplying mulches for each crop. The time between the termination of one crop and the planting of another allows for the germination, emergence, and establishment of weeds in old plant holes. Often, the greatest challenge in plastic mulch vegetable systems is eliminating the first crop and any weeds growing under and through holes in the mulch prior to planting the second crop. Herbicides that can be applied over-the-top of plastic mulch prior to transplanting a crop without damage are crucial for maintaining weed management systems. Previous research has focused on applying herbicides overtop of mulch but prior to vegetable transplant, however no research has been conducted that focuses on herbicide movement off the plastic mulch for subsequent crop rotations. Specifically, there is little to no information available on the accumulation of herbicides, or pesticides in general, into the mulch transplant hole area. Therefore, experiments were conducted to quantify the concentration of herbicides, insecticides, and fungicides going into the transplant hole-punch area from a wash-off event. To quantify the pesticide concentration in the hole-punch area (transplant hole) on plastic mulch from water wash-off, three novel simulated vegetable beds (2.4m long x 76.2 cm wide) with a tandem rainfall/irrigation simulator were designed and constructed. Utilizing 14 glass jars attached under the 'transplant holes' to collect wash-off, samples were taken from each jar and placed directly into a HPLC vial for analysis. The simulated vegetable bed design fills a need for vegetable weed science research due to its levels of mobility and controllability that could not be achieved in field experiments. The beds design allows for research to include all pesticides that could be sprayed over-the-top in vegetable plasticulture systems. The results from these trials can help growers develop sound herbicide, fungicide, and insecticide programs while minimizing crop injury when transplanting into plastic mulch beds.

Investigating Soybean Response from Dicamba and the Environmental and Chemical Influences That Lead to Increased Dicamba Volatility. Matthew Osterholt*[1], William G. Johnson[1], Manoj Ghaste[1], Joshua R. Widhalm[1], Scott McAdam[1], Bryan G. Young[2]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, Brookston, IN (144)

Since the commercial release of dicamba-resistant soybean (*Glycine max* (L.) Merr.) in 2017, off-target movement of dicamba to sensitive plant species has been a major concern. As a result, restrictions that limit the manner in which dicamba may be applied have expanded in recent years. However, a more in-depth understanding of the chemical and environmental factors that influence off-target movement of dicamba may contribute to reducing the future impact to non-target species. To address concerns related to dicamba volatility, controlled environment experiments were conducted to investigate the effect of spray solution pH, concentration of ferrous sulfate ions in spray solution, and variability in volatility among different dicamba salts. Results from these studies will contribute to an improved understanding of the chemical interactions occurring within the spray solution that have the potential to influence dicamba volatility. In a separate field experiment, the presence of simulated dew increased dicamba volatility from dicamba-treated soybean leaves. Additionally, simulated dew on dicamba-sensitive soybean increased soybean injury in the presence of dicamba vapor. Furthermore, herbicide applications of formulated glyphosate and glufosinate with built-in surfactant systems made to dicamba-sensitive soybean, both before and after a simulated dicamba acid exposure event, increased soybean response from dicamba. Future research will be conducted to determine the main route of entry of volatilized dicamba into sensitive plant species and to characterize the physiological response of soybean lines that purportedly have differential sensitivity to dicamba. The overall implications of this research will hopefully lead to improved dicamba application stewardship, understanding environmental influences on dicamba volatility and soybean sensitivity, and provide more insight into why soybean are so sensitive to dicamba.

Using Bacterial Endophyte MS79 as Bioherbicide to Control Weeds. Mohammad R. Alsabri*; University of Kentucky, Lexington, KY (145)

Mohammad Radhi Sahib[1,2], Jozesf Stork[1], Jon S. Thorson,[3,4]Khaled A. Shaaban[3,4]and Seth DeBolt[1] [1] Department of Horticulture, University of Kentucky Lexington, USA [2] Department of Horticulture, Al Qasim Green University Babylon, Iraq [3]Center for Pharmaceutical Research and Innovation, and [4]Department of Pharmaceutical Sciences, College of Pharmacy, University of Kentucky, Lexington, Kentucky 40536, United States

Weeds are a universal problem in agriculture, costing growers billions of dollars annually. Although chemical herbicides have significant effects on weeds, they often lead to herbicide resistance and are not environmentally friendly. The combination of increasing demand for organic food and awareness about harmful effects from chemical pesticides have created a global surge in the development of bioherbicides. However, there are currently few bioherbicides available commercially, driving the need for new herbicidal mechanisms for environmentally friendly weed control. To that end, we are developing a bioherbicide produced by a bacterial strain MS79 that significantly reduced the seedling growth of sorghum and Arabidopsis compared to the controls in the lab. Also-MS79 has suppressed weeds, such as velvet leaf, poison hemlock and johnsongrass in the greenhouse. The mechanism of an active bioherbicide MS79 to suppress plant growth was determined by purification and structure elucidation Indole acetic acid (IAA) and Phenyl-acetic acid (PAA) in the culture media and quantified by using HPLC, GC-MS and NMR. Our next objective is to find a good formulation to trying to produce new bioherbicide.

The Effects of Increased CO_2 Concentration in the Atmosphere on Weed Morphology, Development and Resistance. Juliana de Souza Rodrigues*, Timothy L. Grey; University of Georgia, Tifton, GA (146)

The selection pressure imposed by the reliance on herbicide applications has led to an increase in weed resistant populations. At the current CO_2 and temperature levels, studies have demonstrated different responses from resistant and susceptible weeds to the available management tools that are being used. However, considering the increased cases of herbicide-resistant weeds and going further, to an environment with increased CO_2 levels and temperature, what could change? Herbicide metabolism studies have utilized the ^{14}C-labeled technique to analyze the uptake and the distribution of herbicide through plant tissues. By quantifying and following the herbicide route, it is possible to associate the resistance to reduced absorption or translocation within the plant, as well as accelerated metabolism in many weed species. Along with plant morphology and development, understanding the pathways of herbicide absorption, uptake and metabolism within the plant can further our ability to characterize herbicide movement in plants exposed to high levels of CO_2 and temperature. Based on this, my current research is focused on evaluating palmer amaranth behavior under different climatic scenarios. Growth chambers will be used to simulate high CO_2 concentration and temperature in the environment while observing the overall pattern of herbicide translocation within the plant and to what extent a decrease or increase in herbicide susceptibility will impact palmer's response to glyphosate. With this in mind, we will be able to correlate if palmer amaranth growth will vary in modified environments, and how this can impact actual weed management. In the future, will growers rely on the same weed management practices that are used today? Our goal is to provide information and increase awareness about different weed management strategies for a climate change scenario.

3MT - 3MT MS

Quantifying Vegetable Crops Response to Simulated Dicamba Drift Rates Using Image Analysis Techniques. Maggie H. Wasacz*[1], David J. Mayonado[2], Mark VanGessel[3], Matthew T. Elmore[4], Thierry E. Besancon[5]; [1]Rutgers University, Wall Township, NJ, [2]Affiliation Not Specified, Hebron, MD, [3]University of Delaware, Georgetown, DE, [4]Rutgers University, New Brunswick, NJ, [5]Rutgers University, Chatsworth, NJ (149)

Dicamba is a synthetic auxin herbicide that is prone to off-target movement, including drift and volatilization. Due to the increased acreage of dicamba-tolerant soybean in the mid-Atlantic region to control herbicide-resistant weeds such as Palmer amaranth (*Amaranthus palmeri* S. Watson) and horseweed (*Erigeron canadensis* L.), dicamba drift injury to neighboring vegetable crops is of concern. A methodology was developed based on a method used by Sassenrath-Cole, et al., 1995 to measure leaf deformation caused by dicamba injury. The objective of this method is to quantify crop injury to determine relative sensitivities of several economically important vegetable crops since it is visually difficult to distinguish injury severity between different crop species. This method begins with treating vegetable species of concern with sublethal rates of dicamba to simulate drift rates. Four weeks after treatment, the first leaf that emerges after treatment, which tends to be foliage with peak injury, is removed. This area of this leaf, called the leaf shadow, is measured in its natural configuration using a leaf area scanner. The same leaf is then flattened, and the area is measured again. The leaf shadow is divided by the flattened leaf area to calculate the Leaf Deformation Index (LDI), which can be used to compare leaf deformation severity within a crop species and across different crop species. The leaf deformation data suggest that cucumber is more sensitive to leaf deformation than soybean at 1/250th of label rate treatment, with 58% and 75% leaf area reductions compared to the untreated controls, respectively. However, at the lower 1/2000th of the label rate treatment, soybean is more sensitive to leaf deformation than cucumber, with 80% and 93% leaf area reductions, respectively. Future studies aim to compare several crop species and varieties to establish a registry of vegetable crops and their relative sensitivities that may help refine label recommendations, as well as help growers better design planting strategies around dicamba-treated fields.

What's Old is New Again: Revisiting Alternative Weed Management Strategies for Palmer Amaranth (*Amaranthus palmeri*) Control. Rodger B. Farr*[1], Jason K. Norsworthy[1], Tom Barber[2], Thomas R. Butts[2], Grant L. Priess[1], James W. Beesinger[1]; [1]University of Arkansas, Fayetteville, AR, [2]University of Arkansas System Division of Agriculture, Lonoke, AR (150)

The evolution of herbicide-resistant weeds is one of the greatest threats facing crop production across the United States. As weeds such as Palmer amaranth develop resistance to more herbicide sites of action, the ability to manage these weeds chemically becomes increasingly difficult. In order to combat herbicide-resistant weeds and to slow the development of resistance to the remaining effective chemistries available, producers and scientists alike have looked to integrate practices into their weed management plans that had previously been commonplace. Some of these management practices include the use of deep tillage, cover crops, and overlaying residual herbicides to prevent the emergence of weeds as well as the implementation of a zero-tolerance threshold for exceptionally troublesome weeds to eliminate weed seeds from replenishing the weed seedbank. A long-term study was initiated in 2018 to understand the ecological and economical implications and risks of implementing these integrated management strategies in cotton productions systems. The study was set up as a split-split-split plot with four replications. Cumulative weed emergence was recorded prior to each herbicide application and hand-weeding event. The time to hand-weed each plot and all other management costs were recorded for an economic analysis for each management program. Soil cores were taken from each plot and grown out to measure the soil weed seedbank. Finally, modeling will be conducted to determine the long-term economic and ecological impact of these strategies in terms of delayed herbicide resistance development. So far, research has found that the use of deep tillage and hand weeding have been successful at significantly reducing Palmer amaranth populations by 73 and 63% respectively. Economically, the use of cover crops has been beneficial, primarily due to increased cotton yields. The economic impact of other management strategies have been mixed so far, primarily due to varying environmental factors, but overall have been beneficial. This research will help generate best management practices for producers moving forward as weed management moves into an era beyond complete reliance on chemistries and help preserve the chemistries that are still available.

Use of an Unmanned Aerial System for Detecting Low Rates of 2,4-D Injury in Cotton.
Ubaldo Torres*[1], Peter A. Dotray[2], Kyle R. Russell[1], Wenxuan Guo[3], Murilo M. Maeda[4]; [1]Texas Tech University, Lubbock, TX, [2]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX, [3]Texas Tech University and Texas A&M AgriLife Research, Lubbock, TX, [4]Texas A&M AgriLife Extension, Lubbock, TX (151)

Auxinic herbicides like 2,4-dichlorophenoxyacetic acid (2,4-D) allow cotton growers to use a novel herbicide mode of action to control troublesome weeds including glyphosate-resistant Palmer amaranth (*Amaranthus palmeri* S. Wats). This herbicide is effective at controlling small broadleaf weeds postemergence. However, off-target movement to susceptible cotton varieties is a major concern. Non-tolerant cotton is highly sensitive to 2,4-D and visible symptomology will be apparent within a few hours after exposure. With the use of unmanned aerial systems (UAS), data can be collected to determine the extent and severity of off-target herbicide movement. Research was conducted at the Texas Tech New Deal Research Farm near Lubbock, TX to detect and assess cotton response to low rates of 2,4-D exposure using UAS-based multispectral imagery. Treatments included five low rates of 2,4-D (1.07 g ae ha^{-1}, 2.14 g ae ha^{-1}, 10.7 g ae ha^{-1}, 21.4 g ae ha^{-1}, 107 g ae ha^{-1}), the full labeled rate of 2,4-D (1070 g ae ha^{-1}), and a non-treated control. Herbicides were applied at 140 liters per hectare using a CO_2-pressurized backpack sprayer to DP 1822XF, a non-2,4-D tolerant cotton, at first square plus two weeks. Weekly flights at an altitude of 30 meters were conducted starting at the day of application. Several vegetation indices were applied to the multispectral imagery and differences between treatments were assessed with and without the soil background at three spatial resolutions (1.3 cm $pixel^{-1}$, 5.2 cm $pixel^{-1}$, and 10.4 cm $pixel^{-1}$). Visible injury was observed on all 2,4-D-exposed cotton 6 days after application. Cotton exposed to the highest rate of 2,4-D had the greatest injury and was the most detectable. Several vegetation indices displayed differences between the non-treated control, the low rates, and the full rate starting at 15 days after application. Five vegetation indices, (GSAVI, MNLI, MSAVI2, RDVI, and SAVI) showed similar results with and without the soil background and all three spatial resolutions 15 days after application. Cotton growth and injury increased in the treated plots later in the season, resulting in greater differences and detectability between the lowest rates and the untreated plots using vegetation indices.

Improving Cotton, the Fabric of Your Life. Mary Gracen A. Fuller*; Mississippi State University, Starkville, MS (152)

Cotton is an important fiber crop around the world. It is used to produce textiles, oils, and even money. Cotton production is currently facing many challenges, one of them being the evolution of herbicide resistant weeds. One especially problematic weed is Palmer amaranth, which can reduce fiber quality, reduce cotton yield, and more. The development of alternative weed control tools and techniques are imperative for the future of cotton production. A possible tool is that of allelopathic crops. Allelopathy is when one plant produces chemicals that effect a neighboring plant which can be positive or negative. A negative effect would make it harder for the neighboring plant to grow, which is what we are interested in. I have been working with chromosome substitution (CS) cotton lines in the greenhouse using a stairstep structure to screen them for allelopathic or competitive abilities. I was able to identify four competitive lines (BNTN 16-15, B10, T26lo, and T11sh). I then took these four lines and screened them in a field setting, with one field located in Starkville, MS and the second in Pontotoc, MS. The next step is to analyze these lines in the lab to identify a gene or gene segments that are associated with allelopathy, which can then be entered into breeding programs where this technology will be made available to farmers on the front lines.

Safening of Chloroacetamide Applications with a Rice Seed Treatment. Tristen H. Avent*[1], Jason K. Norsworthy[1], Scott Rushing[2], Andy Hurst[3]; [1]University of Arkansas, Fayetteville, AR, [2]UPL, Jonesboro, AR, [3]UPL, Macon, GA (153)

Evapotranspiration of Palmer Amaranth (*Amaranthus palmeri*) in Corn/soybean and Non-crop Situation Under Subsurface Drip and Center-pivot Irrigation Systems. Jasmine M. Mausbach*[1], Suat Irmak[1], Debalin Sarangi[2], John Lindquist[1], Amit J. Jhala[1]; [1]University of Nebraska - Lincoln, Lincoln, NE, [2]University of Wyoming, Laramie, WY (154)

Palmer amaranth (*Amaranthus palmeri* S. Watson) (PA) is a major biotic constraint in agronomic cropping systems in the United States due to its rapid growth rate and ability to tolerate adverse conditions, among other characteristics. Weed-crop competition models offer a significant tool for understanding and predicting crop yield losses due to crop-weed interference. Research is currently dominated by empirical studies where the effect of different parameters are compared on crop yield. However, within these models, weed characteristics are unknown, which limits our understanding of weed growth and how it interacts with various crop growth parameters. Field experiments were conducted in 2019 and 2020 at UNL's South Central Agricultural Laboratory near Clay Center, NE with the objective to determine the effect of center-pivot (CPI) versus subsurface drip irrigation (SDI) on the average evapotranspiration (ET_a) of PA grown in corn, soybean, and fallow systems in south central Nebraska. Twelve PA plants were transplanted diagonally one meter apart in the middle two rows of four row corn, soybean, and fallow plots under CPI and SDI. Weed-free corn, soybean, and fallow plots were included for comparison. Watermark Granular Matrix soil moisture sensors were installed at 0.3-, 0.6-, 0.9-m depths next to or between three PA and crop plants in each subplot. Soil matric potential data was collected every hour from the time of PA transplanting to crop harvest. In both years, ET_a of PA in all cropping systems were higher under SDI compared to CPI, likely due to increased water availability closer to root systems under SDI. In 2020, ET_a of PA in fallow was higher under SDI (205 mm) compared to CPI (96 mm). Conversely, in 2019, ET_a of PA in fallow was higher under CPI (347 mm) than SDI (186 mm), although this is likely due to lack of a comparison fallow subplot that was included in the 2020 field design. In both years, PA in soybean had a higher ET_a than PA in corn under CPI, while PA in soybean had a lower ET_a than PA in corn under SDI. These results suggest irrigation method does have an effect on ET_a of PA, but also that crop canopy structure in conjunction with irrigation methods could have an effect on PA ET_a. Further studies measuring incoming light and performed at more locations are needed to provide reliable data for PA in crop-weed interaction models.

Auxin-type Herbicide and Rhizobia Application for Weed Control and Nodulation Potential in Auxin-Tolerant Soybean. Joy Amajioyi*, Sharon Clay; South Dakota State University, Brookings, SD (155)

Auxin-tolerant soybean varieties were developed to maximize broadleaf weed control flexibility. However, high auxin levels in roots have been reported to hinder nodulation. This five-site year study (2019 and 2020) examined auxin efficacy to weeds and the impact of foliar applied auxin with and without bradyrhizobia on root nodulation and nodule activity. Uninoculated Enlist (2, 4-D tolerant) and Xtend (dicamba tolerant) soybean varieties were sown at three timings (early, mid and late-season) at three South Dakota (SD) eastern sites [north (2019 only), central, and south]. The previous crop at all locations was corn. Split-plots, with planting date as the whole plot and herbicide treatment as the sub-plot, were used in an RCBD arrangement with four replications. Preemergence herbicides were applied at each planting date to provide residual weed control, and at mid and late-planting dates, to burndown emerged weeds. Post emergent soybean treatments were targeted to be applied at the V3 stage of soybean growth with and without bradyrhizobia. Treatments included no herbicide (+/-rhizobia only), auxin herbicides [(2,4-D and dicamba); +/-rhizobia], 2,4-D + glufosinate (+/-rhizobia), and a PPO herbicide acifluorfen (+/-rhizobia) which provided a non-auxin treatment for comparison. Root samples from all treatments were collected using a 11 cm diameter soil probe centered over the soybean row to a depth of 10 cm at R5 for nodule evaluation. Weed biomass was greatest in the preemergence only treatments at all locations. At northeast location, weed biomass was lowest in dicamba treated plots (9.5 g/m^2 biomass) than in acifluorfen (116.9 g/m^2 biomass) and pre-control (431.1 g/m^2 biomass) plots. Dicamba application to early and mid-season plantings also provided good weed control at southeast, whereas late planting had the greatest weed biomass (>1626 g/m^2). The effect of rhizobia application across sites varied among treatments and planting dates for total and active nodule numbers. However, at the southeast site in 2020, an application of dicamba + rhizobia enhanced nodulation numbers (+30%) and activity (+54%) compared to the dicamba/no rhizobia control (P=0.05) across all planting dates. Although slight increases in rhizobia nodulation and activity were observed at other locations and timings, the average plant greenness index at R5, grain yield, and seed protein values, which could indicate greater nitrogen assimilation, were similar among all treatments. Grain yields were higher for the early and mid-season plantings compared to late season within location, however, herbicide treatments with or without rhizobia did not influence grain yield within a planting date. Although rhizobia application in some cases increased the number of soybean root nodules and activity, its application did not consistently impact yield or yield parameters.

Harvest Loss in Corn and Volunteerism. Trey Stephens*, Jenny Rees, Amit J. Jhala; University of Nebraska - Lincoln, Lincoln, NE (156)

In recent years, prevalence of volunteer corn in production fields across the Midwest has increased, largely due in part to the adoption of herbicide-resistant (HR) hybrids, and reduced tillage systems. With commercialization of multiple HR hybrids, persistence of volunteer corn in rotated and corn-on-corn cropping systems has become more of a management concern. In 2020, 26 production fields in southeastern and south central Nebraska were hand-sampled following corn harvest with the objective of determining the relationship between harvest loss and volunteer corn seed bank additions in both dryland and irrigated systems. In each field, 16 samples of loose kernels and ears were collected from 0.5 m^2 quadrat, with 100 count seed weight calculated and adjusted to 13% moisture content. Preliminary analysis of 2020 samples indicate harvest losses of 348 and 350 kg ha^{-1} for dryland and irrigated corn, respectively. While yield from individual fields are not currently available for all sampled locations, harvest loss measured in 2020 equates to 2.6% in irrigated systems and 3.5% in dryland systems based on the statewide yield (13,382 and 9,885 kg ha^{-1}, respectively) in 2017. Further analysis of harvest-loss and volunteer corn seed bank additions will be conducted using a predictive model.

Effect of Herbicide and Nitrogen Inhibitors on Nitrification in Corn. William Neels*, Amit J. Jhala, Richard Little, Bijesh Maharjan, Laila Puntel, Javed Iqbal; University of Nebraska - Lincoln, Lincoln, NE (157)

Nitrogen management in crops is usually challenging due to nitrogen transformations and losses in soil. Nitrogen transformation in soil occurs through the biological process of nitrification and denitrification. Nitrification is the conversion of ammonium (NH_4^+) to nitrate (NO_3^-) by ammonia oxidizing bacteria (AOB), *Nitrosomonas* and *Nitrobacter*. While plants take up most of the nitrogen in the form of nitrate, this nitrate has the potential to be lost through leaching during heavy precipitation or excessive irrigation events. Nitrification inhibitor products are commonly used to temporarily slow the nitrification process by reducing the abundance of AOB populations. Herbicides can also generate non-target effects on soil microorganisms and can be used as an alternative to slow the nitrification process. Several studies have been conducted in laboratory settings to observe the effects of herbicides on nitrification and nitrate leaching. However, the effect of herbicide on nitrification in field corn (*Zea mays*) production remains uncertain. To evaluate the comparative effects of herbicide and nitrification inhibitors on nitrification, we conducted a field experiment at the University of Nebraska-Lincoln South Central Agricultural Laboratory (SCAL) near Clay Center. Treatments were laid out in a split-plot factorial design with 4 replications. The main plot factor included 3 herbicide treatment levels: 1) No application of pre-emergence herbicide, 2) application of atrazine/bicyclopyrone/mesotrione/s-metolachlor premix, and 3) application of acetochlor/mesotrione/clopyralid premix. The subplot factor included 5 fertilizer treatment levels: 1) no application of nitrogen fertilizer, 2) banded application of anhydrous ammonia with nitrapyrin nitrification inhibitor, 3) banded application of anhydrous ammonia without a nitrification inhibitor, 4) surface broadcast application of urea with dicyandiamide nitrification inhibitor, and 5) surface broadcast application of urea without a nitrification inhibitor. Throughout the growing season, weekly soil samples were collected to determine the treatment effect on nitrification. Herbicide applications did not decrease nitrification at a significant level. Anhydrous ammonia with nitrapyrin generally decreased nitrification and retained ammonium concentrations compared to anhydrous ammonia without nitrapyrin, with significant effects observed at 14 DAT. Similarly, urea with dicyandiamide decreased nitrification and retained ammonium concentrations than urea without dicyandiamide, with significant effects observed at 21 DAT. Nitrogen treatments containing anhydrous retained ammonium concentrations at significantly higher levels when compared to urea treatments. Nitrification inhibitors in both N sources did not impact crop yield; however, anhdyrous ammonia increased crop yield by 16-21% compared to urea application. The results indicate that N source rather than nitrification inhibition through N inhibitors and herbicide is more important in increasing corn grain yield. In the future, more studies would be conducted to evaluate the impact of herbicide, nitrification inhibitors, and nitrogen source on nitrogen transformation and crop yield across variable climatic years.

Economics of Overlapping Residual Herbicide Programs for Control of Glyphosate-resistant Palmer Amaranth in Soybean. Shawn T. McDonald*[1], Adam Striegel[1], Prashant Jha[2], Amit J. Jhala[1]; [1]University of Nebraska - Lincoln, Lincoln, NE, [2]Iowa State University, Ames, IA (158)

Across the United States, the rapid growth and extended germination window of Palmer amaranth have complicated management programs as a single application of a PRE herbicide may not provide season-long control in soybean. Management programs are further challenged by the widespread evolution of glyphosate and ALS-inhibitor-resistant Palmer amaranth in Nebraska. Field experiments were conducted in 2018 and 2019 in a producer's field near Carleton, NE which were infested with glyphosate/ALS-inhibitor-resistant Palmer amaranth to evaluate the effect of PRE followed by (fb) a tank-mixture of foliar active and residual POST herbicide programs in dicamba/glyphosate-resistant soybean. Treatments were arranged in a randomized complete block design with four replications and included a weed-free and non-treated control. All PRE programs provided 94 to 100% reductions in weed biomass 14 d after PRE (DAPRE) in 2019. At 28 DAPRE, all PRE programs provided 80 to 92% control of Palmer amaranth across both site-years. Likewise, in 2019, PRE-only, PRE fb POST, and PRE fb POST + RH programs provided 98 to 100% reductions to Palmer amaranth biomass at 28 DALPOST. All herbicide programs provided similar control at 21 DAPOST in 2018. However, PRE-only programs (94%) provided reduced levels of control in comparison to PRE fb POST (99%) and PRE fb POST + RH (99%) programs in 2019. While soybean yields did not differ across herbicide program in 2018, PRE fb POST + RH programs produced higher yields (4,860 kg ha^{-1}) than PRE-only (4,487 kg ha^{-1}), PRE fb POST (4,569 kg ha^{-1}), and POST fb LPOST (4,537 kg ha^{-1}) programs in 2019. While programs with chlorimuron/flumioxazin/pyroxasulfone fb dicamba + acetochlor & flumioxazin/pyroxasulfone/metribuzin fb dicamba + acetochlor produced negative gross profit margins in 2018 consequentially produced the highest overall gross profit margins 1603.01 \$ ha^{-1} and 1658.54 \$ ha^{-1} in 2019, respectively.

Evaluation of Electrocution as a Method of Managing Problematic Weeds. Haylee E. Schreier*, Kevin W. Bradley, Mandy Bish, Brian Dintelmann; University of Missouri, Columbia, MO (159)

Herbicide-resistant weeds continue to pose a significant threat to sustainable agricultural production, which has led to a renewed interest in alternative methods of weed control. In 2020, electrocution was tested as an alternative method of control of waterhemp *(Amaranthus tuberculatas),* horseweed *(Conyza canadensis),* giant ragweed *(Ambrosia trifida),* common ragweed *(Ambrosia artemisiifolia),* giant foxtail *(Setaria faberi),* and barnyardgrass *(Echinochloa crus-galli)* using an implement called the Weed Zapper ™. Each weed species was evaluated in a separate, bare-ground experiment, and each species was electrocuted at either 4 or 5 different stages of growth through the growing season. At each electrocution timing, plants were electrocuted at speeds of 3.2 or 6.4 km/h, and were electrocuted either once or sequentially one week following the first treatment. Visual weed control ratings were taken at regular intervals after treatment. Overall, results from these experiments indicate that higher levels of weed control were achieved as the weeds grew taller, as this is when the weeds could have more contact with the boom. Greater weed control was also obtained when weeds were electrocuted sequentially at a one -week interval compared to only once. For example, by three days after treatment, 81% waterhemp control was achieved when treated once, while there was 89% control when treated sequentially. By the end of the season, greater than 97% control of horseweed, common and giant ragweed, and waterhemp was achieved, while grass species were controlled from 61 to 96%. Collectively, results from these experiments indicate that weed electrocution has the potential to control late-season weed escapes that are often encountered in soybean production systems. bradleyke@missouri.edu

A Multi-state Evaluation of the Response of Waterhemp Populations to Dicamba and Glufosinate. Travis Winans*, Brian Dintelmann, Mandy Bish, Kevin W. Bradley; University of Missouri, Columbia, MO (160)

Currently, there have been no documented cases of waterhemp with resistance to dicamba or glufosinate. However, there have been multiple instances where a lack of complete control has been reported with either of these herbicides. In 2018 and 2019, a total of 212 waterhemp (*Amaranthus tuberculatus)* populations with suspected resistance, or that remained at the time of soybean harvest were collected from fields in Illinois, Indiana, Louisiana, Missouri, Nebraska, Ohio, and Tennessee. A series of greenhouse experiments were conducted to characterize the extent to which any of these populations were able to withstand applications of dicamba or glufosinate. All waterhemp populations were treated with one-half (1/2X) and labeled (1X) use rates of dicamba and glufosinate once plants reached 8 to 10 cm in height. Visual injury ratings and survival counts were taken 21 days after application. For waterhemp populations collected in 2018, approximately 28 and 8% of plants survived the ″ and 1X rates of dicamba, respectively, while 20% and 7% of plants survived the ″ and 1X rates of glufosinate. A similar response to dicamba was observed in populations collected in 2019, with 28% of plants surviving the 1/2X rate and 6% of plants surviving the 1X rate. Less than 3% of plants from the 2019 populations survived the 1X rate of glufosinate while 26% of plants survived the 1/2X rate. An additional set of 111 waterhemp populations were collected during the 2020 growing season and will be screened in the same manner as described previously in the coming months. Results from this survey help us to understand the potential frequency and distribution of waterhemp resistance to dicamba and glufosinate, two of the most common herbicides that are currently being utilized for post-emergence weed control in soybean production in the United States.

Impact of Tillage Regime and Cover Cropping on Weed Dynamics in Organic Cotton Production. McKenzie J. Barth*, Muthukumar V. Bagavathiannan; Texas A&M University, College Station, TX (161)

Weeds present a major challenge in organic production systems and there is a great need for developing effective weed management options in these systems, while reducing the dependency on destructive tillage. The objective of this study was to evaluate the impact of two tillage systems (strip-till and conventional-till) and four cover crop species (oats, mustard, winter pea, and a mix of all three species) on weed dynamics in organic cotton production. The field experiment was conducted at the Texas A&M field research facility in Burleson County, TX. Observations included weed seedling emergence patterns over the growing season and weed biomass production during mid-season and at harvest. Preliminary results showed that weed control is very challenging in strip-till plots; total crop failure occurred in some of the plots. Cover crops provided significant weed suppression, though the degree of impact varied among the cover crop species, and in the following order of efficacy from high to low: oats, mustard, cover crop mix, and winter pea. Even in strip-till plots with high weed infestations, presence of cover crop residues provided considerable weed suppression. Weed seedling emergence patterns and weed biomass production also followed similar trends with respect to the tillage and cover crop treatments. Findings of this study reveal that cover cropping is a highly valuable tool for weed suppression in organic cotton production, but inclusion of more robust weed management options are necessary in strip-tillage.

Integrated Physical and Cultural Weed Management in Table Beets. Daniel M. Priddy*, Daniel C. Brainard, Zachary D. Hayden, Monique Hemker; Michigan State University, East Lansing, MI (162)

Table beets (*Beta vulgaris)* are among the most challenging crops to mechanically cultivate, but improved understanding and exploitation of cultivar differences in emergence, growth and morphological characteristics may improve cultivation success. In a series of field and greenhouse trials, four beet cultivars—Boro (B), Chioggia Guardsmark (CG), Moneta (M), and Touchstone Gold (TG)— were evaluated for their tolerance to deep planting and mechanical cultivation as well as their competitiveness with escaped weeds. In one set of experiments, seeds of each cultivar were sown at 1, 2, 3 and 4 cm depth and monitored for emergence and early growth under both greenhouse and field conditions. We hypothesized that deep sowing would facilitate stale seed bedding by delaying the time of beet emergence relative to weeds. In a separate field experiment, the effects of cultivar, cultivation tool (finger weeder vs hilling disk) and weed competition (none vs escaped weeds) on weed and beet survival, beet yield and final weed biomass were evaluated. We hypothesized that cultivars with greater root biomass and root anchorage force would be more tolerant to finger weeders, while those with greater shoot biomass and height would be more tolerant to hilling. In emergence studies, we found that under greenhouse conditions, B, CG and TG beet varieties could be planted at 3 or 4 cm depth to delay emergence by 1-2 days relative to shallower seeding depths, potentially allowing for a longer window to stale seedbed. However, under field conditions, emergence from greater depths sometimes resulted in either no difference in emergence timing or reduced total emergence and hence may be an impractical strategy under some soil conditions. In field cultivation studies, we found that cultivars differed in their tolerance to cultivation (CG >TG), as well as competitiveness with weeds (B>CG,M,TG). However, beet mortality was too low and beet characteristics too similar to adequately evaluate relationships between tool tolerance and plant traits. Although yield losses due to weed escapes following cultivation were not detected for any of the varieties, B had both the highest yield and lowest final weed biomass.

Response of Non-Irrigated Peanut to Delayed Flumioxazin Applications. Nicholas L. Hurdle*[1], Timothy L. Grey[2], Walter S. Monfort[2]; [1]University of Georgia, Collierville, TN, [2]University of Georgia, Tifton, GA (163)

Georgia is responsible for over 50% of the U.S. peanut supply on 328,000 hectares across the state. Over 75% and 60% of Georgia and U.S. peanut growers, respectively, utilize flumioxazin for residual weed control. As peanut emerges from soil and through the treated zone, it is inevitable flumioxazin will contact the developing plant material including the roots and shoot. It has been reported that flumioxazin can cause injury, primarily in cool, wet conditions. The herbicide registration indicates injury is possible in these conditions, as well as applications made more than 2 days after planting. There is limited information about the response of peanut to flumioxazin injury under non-irrigated conditions. Research was conducted in Plains and Tifton, GA to investigate the effects of flumioxazin applied at multiple timings and multiple rates on peanut under non-irrigated conditions. Flumioxazin at 27, 54, or 107 g ai ha^{-1} was applied at 0, 3, 5, 7, 10, and 14 days after peanut planting. Data collected included stand counts, plant width, percent injury to the non-treated control, and yield. Data for the 2020 growing seas has been analyzed using Tukey HSD with an alpha of 0.05. In Tifton, as time after planting and rate increased, injury increased being noted as necrotic and chlorotic regions. This injury translated into rate by timing interactions for stand counts, widths, and percent injury to the non-treated control. At both locations, injury to each recorded measurement increased as rate and time after application increased, with the full rate applied 10 or 14 days after planting causing the greatest amount of injury.

Oral Paper presentations:

"Weed Genomics"

The International Weed Genomics Consortium: the Growing Community Resources for Weed Genomics Research. Todd A. Gaines*[1], Eric L. Patterson[2], Sarah Morran[1], Dana R. MacGregor[3], Roland S. Beffa[4], Joseph S. McElroy[5], Mithila Jugulam[6], Patrick Tranel[7]; [1]Colorado State University, Fort Collins, CO, [2]Michigan State University, East Lansing, MI, [3]Rothamsted Research, Harpenden, United Kingdom, [4]Bayer AG, CropScience Division, Frankfort / Main, Germany, [5]Auburn University, Auburn, AL, [6]Kansas State University, Manhattan, KS, [7]University of Illinois, Urbana, IL (164)

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

The Reactivation and Expansion of FHY3/FAR1-Like Genes in *Bassia scoparia* (Kochia) and its Impact of Glyphosate Resistance. Jinyi Chen[1], Nathan D. Hall*[1], Christopher A. Saski[2], Todd A. Gaines[3], Eric L. Patterson[1]; [1]Michigan State University, East Lansing, MI, [2]Clemson University, Clemson, SC, [3]Colorado State University, Fort Collins, CO (165)

Bassia scoparia (kochia) is a weedy species that has developed glyphosate resistance through tandem duplications of the EPSPS loci. Past work demonstrated that these duplications could have been caused by the insertion of a mobile genetic element that contained a FHY3-FAR1-like gene. Here as part of the kochia genome re-sequencing project, we demonstrate the FHY3-FAR1-like gene family is expanded within kochia (when compared to other chenopods) and that the FHY3-FAR1-like gene that occurs within the MGE is part of the Jittery family and is sister to both FHY3 and Far1. The MGE is associated with terminal inverted repeats, target site duplication and possess three conserved domains identified in functional Jittery elements, a DNA binding domain, a zinc finger and a MULE domain. The presence of these domains suggests that the FHY3-FAR1-like gene is a driver of transposition and not just a passenger. In addition to characterizing the FHY3-FAR1-like gene we identify an alternate insertion site of MGE in the newest draft of the glyphosate susceptible kochia genome. Additionally, we use discordant read mapping to identify alternate insertion sites of the MGE in a glyphosate resistant line of kochia. In conclusion, we provide evidence that strongly suggests the MGE responsible for EPSPS is transposed by way of a cut and paste mechanism typical of Type 2 Transposons. Furthermore, we hypothesize that the FHY3-FAR1-like gene we identified is either an example of a "de-domesticated" transcription factor or a "feral" transposon.

Putting it Together: Multiomic Insights into Epigenetic Driven Herbicide Stress Responses.
Suzanne Laliberte*, Gourav Sharma, Jacob Barney, Shawn Askew, James Westwood, David C. Haak; Virginia Tech, Blacksburg, VA (166)

Plants may encounter a variety of abiotic stresses and have evolved ways to cope with many of them. Some of these responses involve epigenetic mechanisms that can alter gene expression without changing the genomic sequence. Epigenetic changes can persist for hours or last through generations. This study is focused on tracking long term epigenetic changes in response to abiotic stress by combining RNAseq, small RNAseq, and whole genome bisulfite sequence data. Young Arabidopsis plants were subjected to sublethal doses of glyphosate herbicide, trifloxysulfuron herbicide, mechanical clipping, and shade. Several weeks later, they flowered, and rosette leaves were harvested for nucleic acid extraction. These were sequenced, and the reads were mapped to the TAIR10 genome. STAR, Bowtie, and Bismark were used to map the RNA, sRNA, and bisulfite sequences, respectively. DESeq2 was used to identify differentially expressed RNA, and Methylkit was used to identify differentially methylated regions. Differential activity was identified for all three data types across all three treatments. With this data, we intend to build a larger matrix to observe overall patterns of epigenetic activity in response to abiotic stress.

How Sub-Lethal Doses of Herbicides and Abiotic Stresses Shape the *Sorghum bicolor* Methylome. Gourav Sharma*, Jacob Barney, Shawn Askew, James Westwood, David C. Haak; Virginia Tech, Blacksburg, VA (167)

Modern herbicides are the most successful and efficient tool for weed control but due to widespread and repetitive use of few herbicides mode of action, weeds develop herbicide resistance. Two general categories of resistance are target-site resistance (TSR) and non-target site resistance (NTSR). TSR mechanisms are well understood and arise from a single point mutation in the herbicide target gene, but those involving NTSR are still poorly understood and could result from several mechanisms. NTSR can confer an unpredictable level of resistance that may also affect response to herbicides with different modes of action, including herbicides not yet marketed. The origin and genetic bases for these resistance mechanisms are not known. The field of epigenetics may contribute to understanding NTSR in that it explains how organisms are able to adapt to various abiotic/biotic stresses through non-sequence based modifications of their DNA, such as changes in methylation status or histone assembly. Herbicides and other management practices to control weeds, such as shading and clipping, impose stress on the weeds. Sub-lethal weed management practices could lead to epigenetic modifications that may facilitate the evolution of resistance, but the role of epigenetic processes in the evolution of herbicide-resistant weeds is still untested. One of the well-studied epigenetic regulatory mechanisms is DNA methylation, which is the addition of a methyl group to cytosine nucleotides in DNA, which can change gene expression. We are working on *Sorghum bicolor* to look at changes in DNA methylation patterns due to the sub-lethal dose of herbicides and other common stresses, seeking to understand whether epigenetic changes are shared or unique among stresses. Methylation occurs in all cytosine sequence contexts of plant DNA: CG, CHG, and CHH (H represents A, T, or C). The tissues from control and stressed plants were collected at standardized maturation levels and subjected to whole-genome, bisulfite sequencing (WGBS). We found the highest levels of methylation in CG (20.5%) context followed by CHG (7.5%) and CHH (4.8%) context. Our results are in accordance with previous studies and indicate that methylation at promoter sites (CpG islands) are crucial for stress adaptations. Further analysis will elucidate the importance of DNA methylation in weed evolution due to herbicides and other management strategies

Analysis of *Poa annua* (Annual Bluegrass) Genome Reveals Subgenome Bias for Herbicide-Resistance-Endowing Mutations. Claudia A. Rutland*, Nathan D. Hall, Joseph S. McElroy; Auburn University, Auburn, AL (168)

Poa annua is an allopolyploid weed of turfgrass systems that has evolved resistance to almost every herbicide mode of action. Allopolyploidy is the product of whole genome duplication following the hybridization of two distinct diploid species, resulting in homologous gene pairs, or homeologs from separate progenitor species. Research suggests that subgenome mutation bias exists in polyploid species. In this study we focused on specific single nucleotide polymorphisms (SNPs) EPSPS (Pro106) and ALS (Trp574) that result in herbicide resistance, and K_a/K_s ratio analysis of transcriptome assemblies to determine if a subgenome bias exists in the progenitor genomes of *P. annua*, *P. supina* and *P. infirma*. Through the utilization of amplicon sequencing (AmpSeq), we were able to determine that there is a bias for mutations to occur in the paternal *Poa supina* subgenome of *Poa annua* over the *Poa infirma* subgenome. Because *P. supina* is the non-dominant genome, more mutations should accumulate, resulting in a mutation biased subgenome. This claim was strengthened based on a K_a/K_s ratio test. More regions should be studied to strengthen our claim, however based on this data we can reasonably assume that *P. annua* does have a subgenome bias towards its progenitor *Poa supina.*

Family Dynamics of EPSPS Gene Copy Number and Gene Flow in Glyphosate-Resistant Kochia. Philip Westra*, Andrew Effertz, Todd A. Gaines, Crystal D. Sparks; Colorado State University, Fort Collins, CO (169)

"Herbicide Efficacy in Horticultural Crops"

Holistic Carrot Production Systems for Season-Long Weed Management: A Model for Other Crops? Jed Colquhoun*, Richard Rittmeyer, Daniel J. Heider; University of Wisconsin - Madison, Madison, WI (170)

Carrot emergence and early season growth is slow and inconsistent, making the crop a poor competitor with weeds. In response, we investigated ways to enhance carrot competitiveness with minimal additional inputs, such as by choosing competitive varieties, seeding configurations and planting dates that favor the crop over weeds. Carrot variety had a moderate influence on carrot foliar canopy development and subsequently weed density. For example, 'Cupar' carrot formed a complete crop canopy sooner than the other dicer-type 'Canada' variety. Likely as a result, density of weed species such as spotted ladysthumb (Polygonum persicaria L.) and common lambsquarters (Chenopodium album L.) was less where Cupar was grown compared to Canada. Gibberellic acid as a foliar application was not successful in these studies, possibly due to warm weather around the time of application, and in a few cases may have even increased weed seed germination and establishment. Adding two carrot rows to the current regional industry standard three-row bed system not only enhanced competitiveness with weeds but also improved carrot yield without additional fertilizer, water or pest management inputs. By far, though, the most successful strategy to reduce weed density while maintaining or improving carrot yield was to delay seeding by 17 to 19 d. We anticipate more holistic production system research that integrates low-input alternatives in other crops as herbicide-resistant weeds proliferate while few new herbicides are developed. The holistic approaches investigated here can be successfully integrated without adding significant economic burden to the farmer or increasing crop failure risk. colquhoun@wisc.edu

Which Way Should Pendimethalin be Applied in Onion: PRE, Delayed PRE, or Early POST? Harlene M. Hatterman-Valenti*, Collin P. Auwarter; North Dakota State University, Fargo, ND (171)

Field studies were conducted at the Oakes Irrigation Research Facility (OIRF) and a grower's field 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. At the OIRF, 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. Similar results occurred in the grower's field. Additional trials are planned to examine the consistency of crop safety and weed control when pendimethalin is applied preemergence, delayed preemergence, or early postemergence since all three application methods performed well for specific cultivars.

Weed Control in Direct-Seeded Onion with Pyroxasulfone Herbicide. Joel Felix*, Joey Ishida; Oregon State University, Ontario, OR (172)

Few herbicides are registered for weed control in onion compared to row crops. In 2019, the herbicide pyroxasulfone received a supplemental label for use to control weeds in onion. A field study was established during spring 2020 at Oregon State University, Malheur Experiment Station to evaluate the response of direct-seeded onion cultivar 'Vaquero' and weed control with pyroxasulfone applied at various rates and application timing. The predominant soil was an Owyhee silt loam with a pH of 7.8 and 2.78% organic matter. Treatments included pyroxasulfone applied PRE at 73, 100, or 146 g ai ha^{-1} followed by bromoxynil 210 g ai ha^{-1} + oxyfluorfen 140 g ai ha^{-1} at 2- and the 4-leaf stage; tank-mixtures of pyroxasulfone 73 or 100 g ai ha^{-1} + bromoxynil 35 g ai ha^{-1} + oxyfluorfen 35 g ai ha^{-1} at 1-leaf growth stage, followed by bromoxynil 210 g ai ha^{-1} + oxyfluorfen 140 g ai ha^{-1} at the 4-leaf stage; pyroxasulfone 73 or 100 g ai ha^{-1} tank mixed with bromoxynil 210 g ai ha^{-1} + oxyfluorfen 140 g ai ha^{-1} at 2- or 4-leaf growth stages. Pyroxasulfone treatments applied starting at the 2- or 4-leaf stage were preceded by the delayed pre-emergence application of pendimethalin at 1,060 g ai ha^{-1}. A grower standard comprised of delayed pre-emergence application of pendimethalin at 1,060 g ai ha^{-1} followed by sequential tank mixture of bromoxynil 210 g ai ha^{-1} + oxyfluorfen 140 g ai ha^{-1} at 2- and 4-leaf growth stages was included. The study area was drip irrigated from April to August and bulbs were harvested in September 2020. Plants were evaluated for visible injury and plots were evaluated for the level of weed control. The number of weeds per plot was assessed on July 10, 2020. Onion injury at 25 days after the 1-leaf or 15 days after the 2-leaf application ranged from 1 to 10% across herbicide treatments. The injury was characterized by chlorosis and scorching, with the later likely caused by the bromoxynil and oxyfluorfen tankmix partners. Subsequent evaluations at 47 days after 1-leaf or 37 days after the 2-leaf stage application timing indicated onion injury had subsided to 0-1% across herbicide treatments. Treatments applied when onions were at the 4-leaf stage caused minimal injury. Mid-season weed counts indicated common lambsquarters ranging from 25 to 32 plants per 9 m^2 compared to 15 to 81 for treatments applied post emergence at 2- or 4-leaf growth stage or 26 for the grower standard. The number of redroot pigweed and hairy nightshade was =1 per 9 m^2 across herbicide treatments. The number of barnyardgrass ranged from 13 to 95 plants per 9 m^2 across PRE treatments compared to 20 to 82 plants per 9 m^2 across post emergence treatments and 50 plants per 9 m^2 for the grower standard. Marketable onion yield ranged from 109 to 123 Mg ha^{-1} for PRE treatments compared to 121 to 135 Mg ha^{-1} across post emergence pyroxasulfone tankmix treatments or 127 MG ha^{-1} for the grower standard. These results indicated improved weed control when pyroxasulfone herbicide is tankmixed with bromoxynil and oxyfluorfen herbicides to manage weeds in direct-seeded onion.

Acorn Squash, Butternut Squash, and Bell Pepper Response to Fomesafen PRE. Stephen L. Meyers*, Jeanine Arana, Brandi C. Woolam; Purdue University, West Lafayette, IN (173)

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 and black plastic mulch was laid. Fomesafen was broadcast-applied to plastic-covered rows 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 double row of 'Aristotle' and 'PS9928320' pepper plugs were transplanted 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. 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 and followed by broadcast fomesafen applications. 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. For both trials, data were subjected to ANOVA by SAS Proc GLM. Mean data were subjected to regression analysis by JMP and fit to appropriate polynomial, logistic, and exponential models. For all crops, injury at 2 and 4 WAP increased with increasing fomesafen rate. Fomesafen rates of 840 and 1,120 g ha^{-1} resulted in decreased bell pepper plant stand. Fancy and no. 2 pepper fruit number displayed a negative linear response to fomesafen rate. Winter squash yield loss due to herbicide injury was very minimal with the exception of the 1,120 g ha^{-1} rate, which resulted in an 18% reduction in yield pooled across both winter squash types. Across both trials, the proposed 1x rate of fomesafen (280 g ha^{-1}) resulted in minimal injury, which was transient and did not reduce crop yield.

Evaluation of Herbicide Combinations for Improving Weed Control Efficacy in Florida Citrus. Ramdas Kanissery*; University of Florida - IFAS, Immokalee, FL (174)

Weed control is a key component for successful production in Florida citrus as warm and humid climate and frequent rainfall make effective weed suppression a challenge in citrus groves. Moreover, repeated use of the same herbicide products and active ingredients with a similar mode of action has resulted in the widespread occurrence of tolerant and difficult to control weeds. Combining multiple herbicides with a different mode of action during a single application is a strategy for improving such weed management constraints. When herbicides are mixed in a single application, it facilitates the use of a lower rate of herbicide products in the tank-mix. Additionally, the number of spraying operations and associated costs can be reduced. Field studies were conducted at the UF-IFAS Southwest Florida Research and Education Center to evaluate the long-term citrus weed control prospects of combining herbicide products in a tank-mix. Compared to using a herbicide product alone, the combination of herbicides in this study exhibited significantly greater and a longer duration (up to 150 days) of citrus weed control. The combination of pre-emergent herbicides (e.g., Indaziflam + Flumioxazin) exhibited a synergistic outcome at different application rate levels tested.

Peppermint (Mentha x Piperita) Response to Post-harvest Application of Tiafenacil. Brandi C. Woolam*, Stephen L. Meyers, Jeanine Arana; Purdue University, West Lafayette, IN (175)

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 ai ha^{-1}, respectively. Injury at lower rates was transient. At 28 DAT predicted injury increased from .32 to 63 % (Run 1) and 2 to 34 % (Run 2) at rates of 25 to 200 g ai 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 % 100 g ha^{-1} and 9 and 10% at 200 g ha^{-1} for Runs 1 and 2, respectively. At 49 DAT, only 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.

“Herbicide Resistance in Turf, Ornamentals, and Horticultural Crops”

Understanding the Basis for Increased 2,4-D Tolerance in Red Clover (*Trifolium pratense*): Field Evaluations, Metabolism, and Gene Expression. Lucas Araujo*[1], Michael Barrett[1], Randy Dinkins[2], Troy Bass[2], Gene Olson[1], Linda D. Williams[1]; [1]University of Kentucky, Lexington, KY, [2]U. S. Department of Agriculture, Lexington, KY (183)

Red clover (*Trifolium pratense*) is a major legume forage crop throughout United States pastures and hayfields. Typically, broadleaf weeds in grass-based pasture systems can be managed by broadcast applications of inexpensive herbicides, such as 2,4-D; however, 2,4-D is not an option for red clover farmers since most cultivars commercially available are sensitive. Red clover breeding efforts have been geared towards developing cultivars with higher 2,4-D tolerance, which would expand broadleaf weed control options in clover forage systems. UK2014 is an experimental cultivar of red clover, bred for adaptability to the transition zone of the United States, and it has demonstrated increased tolerance to 2,4-D in field evaluations. This study presents a quantification of UK2014 level of tolerance and aims to identify the mechanisms that regulate it. UK2014 (U) was compared to one of its parental cultivars, Kenland (K), which is sensitive to 2,4-D. Dose-response studies included rates from L’ X to 8X the recommended 2,4-D field rate (1X = 1.12 kg a.e. ha^{-1}). Such evaluations demonstrated significantly higher tolerance to 2,4-D injury in U (ID_{50} = 3059 g a.e. ha^{-1}) than in K (ID_{50} = 1115 g a.e. ha^{-1}). Dry biomass, however, was detrimentally affected by 2,4-D in a similar manner to comparable herbicide rates in each cultivar. The introduction of 2000 g ha^{-1} of Malathion to each of the 2,4-D treatments on UK2014 (UM) and Kenland (KM) caused significantly higher synthetic auxin symptomatology, but not as a pronounced dry biomass reduction effect. Since red clover is commonly farmed as a short-lived perennial, clover plants from the dose-response studies were harvested two weeks after treatments and allowed to regrow from crowns for two additional weeks. Both UK2014 and Kenland regrowth were significantly affected by the Malathion addition, suggesting the involvement of 2,4-D metabolism mediated by a cytochrome P450. It is worth noting most Kenland plants did not regrow when treated with Malathion. Additional investigation of the physiological mechanisms behind these responses indicated that rapid metabolism of 14C 2,4-D occurs in both UK2014 and Kenland leaf tissues, as early as 4 hours after treatment (4 HAT) with the labeled herbicide. Even though metabolism occurred in both cultivars, an early eluted metabolite rapidly builds-up in the tolerant cultivar (U). At the same time, parent labeled herbicide is substantially reduced in the tolerant cultivar (U) as the time series progresses, with negligible detection at 72 HAT. Further studies in the expression of specific genes in both tolerant and sensitive clove background shall be performed to assess metabolism activity. Significant progress has been made in developing 2,4-D tolerance in UK2014, particularly in terms of persistence after harvest. A surprising amount of 2,4-D tolerance was found in the Kenland background, although an impractical level of injury occurs at field rates.

ALS Inhibitor Resistance in *Cyperus difformis* Has Multiple Metabolic Pathways. Alex R. Ceseski*, Kassim Al-Khatib; University of California - Davis, Davis, CA (184)

Smallflower umbrella sedge (*Cyperus difformis* L.), is a pernicious weed of rice worldwide. Smallflower populations have been confirmed to be resistant to ALS inhibitors throughout the California rice region. Screening many smallflower populations for cross-resistance to ALS inhibitors has revealed six major resistance patterns, suggesting multiple mechanisms of resistance. Dose-response studies strongly indicated that non-target resistance is common in these populations. Non-target resistance is often mediated by enhanced metabolism, through increased activity of detoxifying enzymes such as cytrochrome-P450 (P450), Glutathione S-transferase (GST), or glucosyl transferase (GT). Identification of metabolites from herbicide breakdown can aid in determining enhanced metabolic pathways of herbicide degradation. Smallflower populations from each ALS cross-resistance pattern were studied using liquid chromatography and mass spectrometry (LC-MS) to identify the relative abundances of major and minor metabolites of four ALS inhibitors at several timepoints after application. Populations were treated with the ALS inhibitors bensulfuron-methyl, halosulfuron-methyl, bispyribac-sodium, and penoxsulam, at 70, 70, 37, and 42 g ai ha^{-1}, respectively, in a bench-type sprayer fitted with one 8002EVS tip, delivering 187 L ha^{-1}. Aboveground tissues were harvested at 12, 24, and 48 hours after treatment (HAT), and kept at -80°C before being subjected to LC-MS analysis. Bensulfuron analysis revealed two isomeric O-demethylated metabolites. Smallflower population R59 had a 2.4-fold increase in the combined isomers by 48 HAT over the susceptible population (SUS), suggesting enhanced P450 activity in R59. Two major and four minor metabolites of halosulfuron were detected. Halosulfuron metabolite profiles suggest enhanced GT activity in R4 and R59, with 1.9 and 1.7-fold respective increases in glycosylated metabolites over SUS. Populations R4 and R10 also had 1.6 and 1.9-fold respective increases in O-demethylated halosulfuron over SUS, further suggesting enhanced P450 activity. Bispyribac analysis yielded two major and two minor metabolites, however the only detected increase in metabolism over susceptible by 48 HAT was for R10, with a 2.25-fold increase of O-demethylated bispyribac, indicating increased P450 metabolism for that population. Penoxsulam analysis revealed four metabolites. The metabolite 2-hydroxyphenyl-penoxsulam was increased approximately 2.0-fold over SUS in R3, R41, and R59. An unidentified glycosylated penoxsulam metabolite also increased 1.75-fold over SUS in population R59. The combined results suggest that enhanced P450 and GT activity are present in populations R4, R10, R41, and R59, leading to differential ALS inhibitor cross-resistance. Knowledge of differential resistance can aid California rice growers and advisers in tailoring field-specific herbicide programs to minimize yield loss and slow the spread of resistance.

Indaziflam Resistance in Annual Bluegrass (*Poa annua* L). Jinyi Chen*[1], Eric L. Patterson[2]; [1]Michigan State University, East Lansing, MI, [2]Clemson University, Clemson, SC (185)

Looking for the target binding protein of Indaziflam Jinyi Chen [1], Peter Lundquist [2], Eric Patterson[1] 1. Michigan State University, Department of Plant, Soil, and Microbial Sciences 2. Michigan State University, Department of Biochemistry and Molecular Biology

Indaziflam is a broad-spectrum herbicide that is mainly used in established permanent crops such as fruit trees, and perennial sugarcane, lawns, golf course etc. Indaziflam is a cellulose-biosynthesis inhibitor (CBI), which inhibits the synthesis of plant cellulose, with the symptoms of radial swelling and ectopic lignification. So far, *Poa annua* is the only weed species reported to have evolved resistance to indaziflam, with the mechanisms unknown. Additionally, there is no cross-resistance between indaziflam and other CBIs, suggesting indaziflam inhibits plant growth in a novel way. To better understand how indaziflam interacts with plant proteins in the cellulose synthesis process, unrevealing the accurate binding target protein of indaziflam is necessary. Also, the identification of indaziflam binding protein will offer a means to predict possible herbicide resistance mutations, as well as making indaziflam last long as a good herbicide. Here, we investigated indaziflam's binding protein through pull-down using indaziflam-conjugated beads with root lysate from Arabidopsis. Elution from these beads contained proteins specifically binding with Indaziflam. By proteomics, we were able to identify some likely indaziflam-binding proteins and generate a high impact candidate list. Among these candidate proteins, the ones associated with endocytosis and transportation are prominent. This list provides a valuable resource towards identifying genes that confer indaziflam resistance, and possibly engineering novel indaziflam resistance.

Identification of Goosegrass (*Eleusine indica*) Resistant to Dithiopyr and Dinitroaniline Herbicides. Eli C. Russell*; Auburn University, Auburn, AL (186)

Goosegrass (*Eleusine indica*) is a summer annual grassy weed that is a problematic weed in turfgrass. Dithiopyr and dinitroanilines are mitotic-inhibiting herbicides that are commonly used as a preemergent application to control goosegrass. A suspected resistant goosegrass population was collected from a golf course putting green and was evaluated for possible resistance to dithiopyr and prodiamine. After rate response evaluation, the alpha-tubulin gene was sequenced for any target-site mutations that have been reported to confer resistance to mitotic-inhibiting herbicides. A mutation was discovered that resulted in an amino acid substitution at position 136 from leucine to phenylalanine (Leu136Phe). Previous research has indicated that Leu136Phe does confer resistance to dinitroaniline herbicides. The level of resistance indicated by regression models and IC50 values indicates that there is roughly a >100, 1.5, 5.5, >100-fold resistance to dithiopyr, prodiamine, pendimethalin, and oryzalin, respectively when compared to the susceptible population. These results indicate that the amount needed of dithiopyr, pendimethalin, and oryzalin to control the resistant population was significantly higher than the susceptible population, while the amount needed for prodiamine was only marginally higher. We, therefore, posit that Leu136Phe in alpha-tubulin induces resistance to dithiopyr and the dinitroanilines pendimethalin and oryzalin but may not induce resistance to prodiamine.

Control of Purple Amaranth, an Emerging Weed in Michigan Vegetable Production.
Sushila Chaudhari*, Erin C. Hill; Michigan State University, East Lansing, MI (188)

“Potential for Pesticide Movement and Impacts”

Pesticide Movement in the Atmosphere: It's Complicated. Mandy Bish*, Eric G. Oseland, Kevin W. Bradley; University of Missouri, Columbia, MO (189)

Weather conditions at ground level are often considered at the time of a ground pesticide application. However, there is typically less emphasis on conditions higher in the atmosphere at application or the day(s) following application. The extensive damage caused by off-target movement of dicamba in recent years has resulted in a need to better understand the role of the atmosphere in pesticide transport. Literature suggests that atmospheric turbulence is a key contributor to dispersal and dilution of pesticides in the air. Within this discussion, we will share some basic principles about atmospheric conditions that can favor pesticide transport and discuss how research being conducted on off-target dicamba movement is enhancing our understanding of this phenomenon. A summary of inversion and wind speed data across multiple geographies will be presented, along with some recent air sampling and deposition results that contribute to our current understanding of off-target pesticide movement. With increases in public awareness of pesticide movement and also with the variety of herbicide-resistant trait options currently available, the need to understand secondary movement of pesticides is essential.

Evaluation of Dicamba Volatility Reducing Agents Under Different Environmental Conditions. Ryan D. Langemeier*[1], Steve Li[1], Rodrigo Werle[2], Greg Kruger[3], Katilyn J. Price[1], Sarah V. Striegel[2], Bruno C. Vieira[4]; [1]Auburn University, Auburn, AL, [2]University of Wisconsin - Madison, Madison, WI, [3]University of Nebraska - Lincoln, North Platte, NE, [4]University of Nebraska - Lincoln, Lincoln, NE (190)

Dicamba tolerant crops are widely planted in soybean and cotton growing regions of the United States. Dicamba is commonly tank mixed with glyphosate to achieve broad spectrum control, but dicamba volatility may increase when tank mixed as glyphosate lowers the pH of the spray solution. In 2020, dicamba was reregistered for over-the-top use on Xtend/Xtendflex crops, however the addition of a volatility reducing agent (VRA) is now required. Little literature is available about the comparative effectiveness of potential VRAs, and a study was designed with the objective of evaluating five different VRA active ingredients across two different growing environments. In June 2020, field experiments were conducted in Macon county, Alabama and Columbia county, Wisconsin. Treatments consisted of five reagent grade VRAs and one commercial foliar fertilizer product (Agripotash) tank mixed with dicamba (Engenia) at 560 g ae ha^{-1} and glyphosate (Roundup Powermax II) at 1260 g ae ha^{-1}, a chemical control (glyphosate + dicamba) which received no buffer, and a non-treated control. Treatments were applied to four greenhouse flats filled with soil at field capacity two times at 140 L ha^{-1} to achieve a total rate of 1120 and 2520 g ae ha^{-1} of dicamba and glyphosate, respectively. The soil flats were placed inside of an open low tunnel (6.096 m in length) between two rows of sensitive soybeans for 48 hours. Visual injury was recorded at 14, 21, and 28 days after treatment (DAT). Soybean width and height was recorded at 28 DAT. Air inside the low tunnels were sampled continuously in every low tunnel except the non-treated controls for the entire 48 hours. VRAs increased the glyphosate + dicamba tank mix pH to a range of 6.8-7.5, except for potassium acetate which was ~5.3. Average visual injury to chemical control plots was 10% in Wisconsin and 28% in Alabama. Treatments with VRAs had significantly less injury at both sites relative to the non-treated control. Average visual injury to treatments with VRAs ranged from 2 to 6% in Alabama, and 1 to 2% in Wisconsin. The chemical control resulted in significantly reduced soybean heights and widths in Alabama but not in Wisconsin. Dicamba air concentration reductions relative to the chemical control ranged from 83-96% in Alabama and 58-87% in Wisconsin across all VRAs. Other commercial foliar fertilizers in addition to Agropotash may be effective VRAs, but are not labeled as VRAs. Our results indicate that all VRA active ingredients evaluated in this study effectively reduced dicamba volatilization in different environments.

Characterize the Effect of Off-Target Synthetic Auxin Exposure to Tobacco. Patrick J. Maxwell*, Travis Gannon, Matthew C. Vann; North Carolina State University, Raleigh, NC (191)

The introduction of synthetic auxin-tolerant crop varieties has enabled over-the-top applications of these herbicides and led to a significant rise in their use in recent years. This trend is concerning for producers growing sensitive crops, such as flue-cured tobacco in proximity to 2,4-D- or dicamba-tolerant crop varieties. While yield reduction is a concern, tobacco exposed to 2,4-D or dicamba (nonregistered herbicide in tobacco) can have severe consequences for the marketability of the crop. A field experiment was conducted in Oxford, NC to evaluate flue-cured tobacco response to five reduced 2,4-D and dicamba rates ranging from 1/8th to 1/1024th of a labeled rate applied 6, 9, 13, or 17 weeks after transplanting (WAT). Within 13 and 17 WAT timings, tobacco tissue was collected 3, 7, and 14 days after treatment (DAT) for subsequent residue analysis. In general, tobacco exposed to dicamba was more injurious (22 to 72%) compared to 2,4-D (9 to 56%), with less injury occurring as the time from transplanting and application increased. Plant height reduction data followed similar trends to plant injury data, although to a lesser degree. Dicamba applied 6 or 9 WAT at the highest test rate (1/8th) reduced plant height 32% and 27%, respectively, whereas all other evaluated application timings and herbicide treatments reduced plant height <20%; however, injury and height reduction data did not directly translate to yield reductions, which ranged from 2 to 26% across herbicide treatments and application timings. When applied at the highest test rate, 2,4-D (133 g ae ha^{-1}) was detected in tobacco vegetation 3, 7 and 14 DAT (0.28 to 2.54 ppm), while dicamba (70 g ae ha^{-1}) was only detected at 3 and 7 DAT (0.02 to 0.55). Information from this study improves our understanding of tobacco sensitivity to 2,4-D and dicamba relative to the tobacco growth stage and provides insights regarding the length of time residues may be detectable following an exposure event.

Impact of Spray Target Surface and Glufosinate on Dicamba Volatility. Maria Leticia M. Zaccaro*, Jason K. Norsworthy, Leonard B. Piveta, Michael M. Houston; University of Arkansas, Fayetteville, AR (192)

Previous research reported an additive effect of mixing glufosinate with dicamba to control glyphosate-resistant weeds such as giant ragweed. However, current labels do not allow glufosinate to be mixed with dicamba in crops having engineered resistance to both crops (XtendFlex technology). The purpose of this experiment was to evaluate if an application of glufosinate prior to dicamba would reduce the secondary movement of dicamba, regardless of the type of target surface. Treatments were set as a factorial arrangement in an RCB design, with 3 replications. Factor-A was glufosinate application timing (4 days before dicamba plus glyphosate application or in a mixture), and factor-B was treated surface (bareground soil or XtendFlex cotton). Field experiments were conducted in 2018, 2019, and 2020 at the Milo J. Shult Agricultural Research & Extension Center in Fayetteville, Arkansas. Low tunnels measuring 6-m in length were constructed over two rows of non-dicamba-resistant soybean (*Glycine max* (L.) Merr.). Treatments were applied to soil or XtendFlex cotton seedlings (100% canopy closure) contained in 53 x 41 x 5.5 cm-trays, at a location approximately 1-km away from the research sites. Following the application, trays were carried to the field and placed at the center of each tunnel on either side of a high-volume air sampler. The air samplers and soybean bioindicators were exposed to the treatments for 48 hours, and after which the tunnel structures and trays were removed. Visual injury and distance from the center of the plot until soybean injury was 5% were evaluated at 14, 21, and 28 days after treatment (DAT). The pH of the spray solutions was tested, and the concentration of dicamba trapped in the air sample filters was analyzed in the laboratory. The pH of the treatments containing glufosinate with dicamba plus glyphosate was similarly low (4.7 pH units) compared to the solution lacking glufosinate (4.6 pH units). Average injury to bioindicators increased by 4% when treatments were applied in a mixture, regardless of treated surface. With data pooled over treated surface, the distance traveled for dicamba symptoms was greater when glufosinate and dicamba were applied in combination. These results demonstrate that keeping glufosinate applications separated from dicamba applications will reduce the risk for off-target movement of dicamba via volatilization.

Snap Bean Morphological and Yield Response to Sublethal Rates of Dicamba. Maggie H. Wasacz*[1], Baylee L. Carr[2], Mark VanGessel[3], Lynn M. Sosnoskie[4], Thierry E. Besancon[2]; [1]Rutgers University, Wall Township, NJ, [2]Rutgers University, Chatsworth, NJ, [3]University of Delaware, Georgetown, DE, [4]Cornell University, Geneva, NY (193)

Dicamba is a synthetic auxin herbicide that is prone to volatilization and drift, which may put neighboring dicamba-sensitive crops at risk. The spread of herbicide resistant Palmer amaranth (*Amaranthus palmeri* S. Watson) and horseweed (*Erigeron canadensis* L.) has contributed to increasing the acreage of dicamba-tolerant soybean in the mid-Atlantic region. This research seeks to determine the sensitivity of field-grown snap beans (*Phaseolus vulgaris* L.) to simulated drift rates of dicamba. In Summer 2020, similar field research was conducted in Bridgeton, NJ, and Geneva, NY. Snap beans of 'Caprice' and 'Huntington' varieties were exposed to six micro-rates of dicamba (fractions of the soybean recommended label rate [560 g a.e. ha^{-1}]: 1/250, 1/500, 1/1000, 1/5000, 1/10000, and untreated control) at two application timings (V2 and R1). After applications, visual injury ratings were taken 2 and 4 weeks after treatment. Snap beans were harvested, sorted, and weighed. Fresh plant biomass was measured in each plot. Snap bean plants showed injury symptoms including leaf deformation, mild chlorosis, stunting, epinasty, and bean deformation. Visual injury ratings suggest that plant injury was more severe at the V2 stage, and that all treatments except for the 1/10000 rate were significantly different than the untreated control plots. Visual injury at the V2 application timing was greater than 50% for the 1/250 and 1/500 treatments. Total bean yield data suggest that application at 1/250, 1/500, and 1/1000 of the labeled rate significantly reduced yields by 63%, 48%, and 26% on average, respectively, compared to the untreated control. However, there was no significant effect of application timing on bean yield. Biomass data indicate that plant biomass is not significantly affected by sublethal rates of dicamba, with the exception of the highest rate applied (1/250 of the labeled rate) which was significantly lower than the untreated control, with a 32% biomass reduction on average. Height data suggests that stunting occurs only in plants treated at the V2 stage, with no significant effect of rate on plant height. These preliminary results suggest that snap bean is a highly sensitive crop to dicamba injury. Future studies involve replication in 2021 and potentially with other vegetable crops.

Response of Peach Trees to Low Rates of Dicamba Using Sequential Applications and Varying Droplet Sizes. Matthew B. Bertucci*, Jason K. Norsworthy, Michael M. Houston, Leonard B. Piveta; University of Arkansas, Fayetteville, AR (194)

Experiments were conducted in summer of 2020 to assess the sensitivity of container-grown peaches to low rates of dicamba to sequential exposure events or to applications with varying droplet sizes. For sequential exposures, peaches were treated with dicamba at 5.6 g ae ha^{-1} (1/100 field rate) at each application after peach leaves had fully opened. Treatment levels included an untreated control receiving no herbicide, one treatment receiving only the initial application, and three treatments receiving the initial application plus sequential applications at the same rate occurring 2 wk, 4 wk, 2 wk + 4 wk after initial application, respectively. For the varying droplet size and spray volume experiment, peaches were treated with dicamba at 11.2 g ae ha^{-1} (1/50 field rate) rate after peach leaves had fully opened. Droplet sizes were determined by nozzle type, which included TTI 11002, TT 11002, AIXR 11002 and XR 11002 applied at 187 L ha^{-1} and XR 1100067 applied at 47 L ha^{-1}. Plant measurements included stem diameter and plant height at application and 3 mo after application, SPAD measurements at application and 28, 56, and 84 d after application (DAA), visual injury ratings and vigor ratings 0, 14, and 56 DAA. Dicamba residue was analyzed from leaf tissue sampled at 14 DAA and 69 DAA. Visual injury ratings were most apparent in the droplet size study. At 14 DAA, mean injury ratings ranged from 14 to 24% with treatment applied at 187 L ha^{-1} but were only 4% in the treatment applied at 47 L ha^{-1}. When sampled 14 DAA, dicamba residues were detected at 90, 86, 70, and 48 ppb from AIXR 11002, TT 11002, TTI 1102, and XR 11002, respectively. No dicamba residues were detected from treatments applied with XR 1100067 nozzles.

“Connecting with Our Stakeholders”

Connecting Electronically with Farmers and Agronomy Professionals. Jeanne S. Falk Jones*; Kansas State University, Colby, KS (195)

With restrictions on connecting with our clientele in person, there has been an added emphasis on connecting with farmers and agronomy professionals electronically. This can be done in a variety of ways, including virtual meetings and social media. The K-State Crop Pest Management School, Cover Your Acres and the Virtual Crop Talk webinar series are meetings that were held virtually in northwest Kansas in 2020-2021. These virtual meetings replaced the same in-person meetings that are held annually. Registration for the online K-State Crop Pest Management School was about 60% of normal registration for the same school held in-person. The number of attendees for Cover Your Acres was nearly the same for the conference held virtually in 2021 to in-person in 2020. The format of the K-State Crop Pest Management School remained the same with a day-long meeting, resulting in eight hours of educational delivery. The format of the Cover Your Acres Winter conference changed from a 2-day conference, with ten presentations to an afternoon program, with five presentations. The Virtual Crop Talk webinar series was the replacement for numerous local meetings on area-specific topics (i.e. Palmer amaranth control in irrigated cropping systems). One specific effort by the organizers and presenters was an increased amount of facilitated interaction with the audience. This was done by utilizing poll questions throughout the presentations via Zoom webinar or Poll Everywhere. In addition, attendees could send in questions using the chat box, Q&A box, email or text message. In surveying the attendees of these virtual meetings, a majority rated virtual meetings as 'OK'. Many like the opportunity to attend meetings that they would not normally attend. Others would like to return to in-person meetings. The attendees noted that they liked the interaction with the speakers. When listing disadvantages, many noted poor/slow internet service and lack of learning from other farmers.

Farmer's Perception of Weedy Rice (*Oryza sativa* Var *spontanea*) from Southern Luzon, Philippines. Analiza Henedina M. Ramirez*, Clare Hazel R. Tabernilla, Priscilla M. Barcial; UP Los Banos, College, Los Banos, Laguna, Philippines (196)

Lack of awareness among farmers on emerging weed problems may contribute to the weed's continuous spread and occurrence. Weedy rice is an emerging problem in rice areas in the Philippines. A survey was conducted to determine the farmers' perception and knowledge on weedy rice covering three municipalities of Batangas and Quezon. A total of 179 farmers were interviewed using a questionnaire that includes questions on the morphological and physiological characteristics of weedy rice. Farmers from San Juan, Batangas were perceived to have the highest level of knowledge while farmers from Tayabas, Quezon were perceived to have the lowest level of knowledge on weedy rice. Farmers from the three municipalities had varying perceptions on the attributes of weedy rice such as its shattering, palatability and physiological attributes such as its dormancy and persistence in soil. In spite of these, farmer respondents considered weedy rice as pest in rice. Furthermore, the respondents from the municipalities relatively had little knowledge on the morphological characteristics of weedy rice particularly on its varying awn, flag leaf, grain and panicle type. There is a need for active dissemination of information on weedy rice and its characteristics in order to properly identify it, minimize its damage and prevent its further spread. amramirez@up.edu.ph Keywords: Survey, *Oryza sativa* var *spontanea*, morphological characteristics

Bridging the Knowing-Doing Gap in the Science, Policy, and Management of Invasive Species. Jacob Barney*, Vasiliy T. Lakoba, David C. Haak, Scott Salom, Todd Schenk, Bryan Brown; Virginia Tech, Blacksburg, VA (197)

Biological invasions are one of the existential threats to global biosecurity. The rate of new introductions continues to rise with no signs of slowing in the future. Furthermore, global change is likely to exacerbate the impacts of invasions on food security, human health, and ecosystem function and services. Like many wicked problems, biological invasions present no clear solution to this complex problem and involve a large number of actors and stakeholders. A tremendous amount of scientific information has been generated in the last half century, but the availability of this information and translation of that information into policy terms is poorly understood. The Invasive Species Working Group at Virginia Tech, a subset of faculty affiliates of the Global Change Center, is addressing this knowing-doing gap. To date, we have convened two workshops designed to engage stakeholders from across Virginia to improve engagement and communication. Our first workshop, *Biological Invasions: Confronting a Crisis*, engaged over 60 participants including researchers, extension personnel, educators, local, state, and federal agencies, nongovernmental organizations, and land managers working on invasive species in Virginia. Through a series of keynote talks, active-engagement sessions, think-pair-share, and community reporting, a broad consensus was reached on the urgent need for a multi-stakeholder coalition, with a focus on communication across stakeholder groups and information sharing. We next held a *Devising Seminar on Biological Invasions* in Richmond, VA engaging key stakeholders to develop a plan to address management barriers in Virginia. Stakeholders came up with policy, social, and technical action items that are worth considering and putting into place in a strategic way. We have also taught three graduate courses largely designed to understand the complex interactions and drivers of the science-policy interface. We continue our work engaging stakeholders, building statewide capacity, and bridging the knowing-doing gap.

A Review of Selected Published Herbicide Resistance Validations. Harry J. Strek*[1], Ian M. Heap[2], Mark Peterson[3]; [1]Bayer AG, Frankfurt / Main, Germany, [2]WeedScience LLC, Corvallis, OR, [3]Affiliation Not Specified, West Lafayette, IN (199)

A literature review of over 70 selected journal publications presenting experiments validating herbicide resistance was conducted to assess adherence to guidelines provided by the Herbicide Resistance Action Committee. The results indicated that most authors were following the guidelines for conducting the experimentation required to accept a unique case in The International Herbicide-Resistant Weed Database (online). Most dose-response studies used appropriate sensitive biotypes, numbers of doses, application methods, replications, response parameters, and methods to calculate GR_{50} values essential for establishing the Resistance Factor. However, in a small number of publications the authors chose to deviate from one or more of the guidelines or made errors in calculating the dose-response curves. The implications of these findings will be discussed.

Insights into Publishing in Weed Science. William K. Vencill*; University of Georgia, Athens, GA (200)

For the 12 months preceding December 31, 2020, 229 manuscripts were submitted to *Weed Science* compared with 233 in the previous 12-month period. Of the manuscripts submitted, 43.8% were accepted compared with 36.4% the previous year. The time from submission to first decision was 36.9 d this past year compared to 35.6 days for the previous year. We are happy to report that the impact factor for *Weed Science* increased from 2.00 to 2.258 for this past year and the 5-year impact factor increased from 2.301 to 2.441. For the year preceding October 1, 2020, the journal depended on 213 unique reviewers. The excellent reputation of the journal would not be possible without the cutting-edge research submitted by authors and the diligent work of the editorial board and the hundreds of referred reviews that are submitted annually.

“Studying Herbicide-Resistant Waterhemp”

The Genetic Architecture of HPPD-Inhibitor Resistance in *Amaranthus tuberculatus*.. Brent P. Murphy*, Patrick Tranel; University of Illinois, Urbana, IL (201)

Having evolved resistance to herbicides spanning seven sites of action, waterhemp (*Amaranthus tuberculatus*) is a driver weed species within the American Midwest. Inhibitors of hydroxyphenylpyruvate dioxygenase (HPPD) are important chemistries for weed management in multiple cropping systems. The characterization of resistance to HPPD-inhibitors will provide insight into the stewardship of these chemistries. We characterized the genetic architecture that underlies the HPPD-inhibitor resistance trait in a waterhemp population from Nebraska, USA. Resistance factors of 15 and 21 were observed within the parental and F_1 generations, respectively, in response to tembotrione, and segregation analysis in a pseudo-F_2 population suggested the trait was complex. Broad-sense heritability of the trait suggests moderate heritability ($H^2 = 0.556$) in this population. Bulk-segregant analysis was used to characterize the genetic architecture of the trait. Five putative quantitative trait loci (QTL), of which two were validated through molecular marker analysis, were identified as associated with the HPPD-inhibitor trait. QTL mapping is a powerful approach to characterize complex traits, and the generation of molecular markers within each QTL will allow for the isolation of causal resistance factors for physiological characterization and functional validation.

Identifying and Quantifying Resistance to Soil-Applied Herbicides in Multiple-Resistant Waterhemp (*Amaranthus tuberculatus*) Seedlings Using a Soilless Greenhouse Assay. Dylan R. Kerr*, Seth A. Strom, Jeanaflor Crystal T. Concepcion, Dean E. Riechers; University of Illinois, Urbana, IL (202)

Previous research demonstrated two MHR waterhemp (*Amaranthus tuberculatus*) populations (CHR and SIR) from Illinois are resistant to several Group 15 herbicides, notably *S*-metolachlor, in the field and greenhouse. Preemergence (PRE) herbicide efficacy is affected by edaphic factors such as organic matter, pH, soil texture, application timing, and rainfall amount. The goal of this research was to limit and control edaphic effects on PRE herbicides by developing a soilless assay, using vermiculite to characterize resistance to two PRE herbicides. Two Group 15 herbicide-resistant (CHR and SIR) and -sensitive (ACR and SEN) waterhemp populations were studied. Dose-response experiments were conducted under greenhouse conditions with pre-germinated seeds from each waterhemp population. Seeds were planted on the vermiculite surface, which had been saturated with *S*-metolachlor or pyroxasulfone 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, then seedlings were counted, and above-ground biomass was harvested 14 days after herbicide treatment. 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 ratios were calculated using these LD_{50} values, which were 18 and 17 for CHR and SIR treated with *S*-metolachlor and 4, and 3 for CHR and SIR treated with pyroxasulfone. Dose-response experiments using *S*-metolachlor either with or without malathion were conducted to compare GR_{50} values. GR_{50} values for *S*-metolachlor alone compared to *S*-metolachlor with malathion changed from 0.87 to 0.47 µM, 0.14 to 0.36 µM, and 0.07 to 0.04 µM for CHR, SIR, and ACR, respectively. Results from these soilless assays are consistent with previously published findings in soil-based systems demonstrating that CHR and SIR are resistant to *S*-metolachlor and pyroxasulfone. In summary, this soilless method could provide an effective and efficient alternative to soil-based systems for studying suspected PRE herbicide-resistant populations, in the absence of edaphic factors, and potentially identifying metabolism-based resistance on a relatively small scale. This method could be altered to meet the requirements of many types of dose-response or weed physiology experiments.

Resistance Mechanism to a Non-Selective HPPD-inhibiting Herbicide in Waterhemp Involves Multiple Detoxification Pathways. Jeanaflor Crystal T. Concepcion*[1], Shiv S. Kaundun[2], James A. Morris[2], Sarah-Jane Hutchings[2], Anatoli V. Lygin[1], Dean E. Riechers[1]; [1]University of Illinois, Urbana, IL, [2]Syngenta, Bracknell, United Kingdom (203)

Oxidative herbicide metabolism via cytochrome P450s is a widely reported resistance mechanism towards commercial 4-hydroxyphenylpyruvate dioxygenase (HPPD, EC 1.13.11.27)-inhibiting herbicides among multiple herbicide-resistant (MHR) waterhemp (*Amaranthus tuberculatus*) and Palmer amaranth (*A. palmeri*) populations. This current research aims to investigate non-target-site resistance mechanism(s) for a presumably metabolically-blocked and non-corn-selective HPPD-inhibiting herbicide called syncarpic acid-3 (SA3) in two MHR populations (SIR and NEB) compared with two HPPD inhibitor-sensitive populations (ACR and SEN). We hypothesized that MHR waterhemp possesses a unique metabolic activity that is either not present or not active in corn. Dose-response experiments of SA3 at nine rates (ranging from 12.5-3200 g ai/ha) clearly differentiated the sensitive and MHR populations. In parallel, metabolism of unlabeled SA3 (300 µM) during a 16-hour time course with excised leaves showed that MHR populations metabolize SA3 faster than sensitive populations. To identify SA3 metabolites, untargeted metabolomics via LC-MS was conducted across two independent experiments: i) excised leaf assay, consisting of three biological replicates, for SIR and ACR populations at 4 and 12 hours, and ii) whole-plant assay, consisting of five biological replicates, for SIR, NEB, ACR and SEN at 12 and 24 hours. Untargeted metabolomics via LC-MS revealed several putative SA3 metabolites, with each having a characteristic MS fragment ion *m/z* 213 [M-H] observed in parent SA3, implying that metabolism of SA3 is not occurring in the (2,4-bis)trifluoromethyl-substituted aryl ring. Evidence of Phase I metabolites include putative hydroxy-SA3, reduced-SA3 and dehydrated-SA3 metabolites. Among the structurally plausible and most characterizing metabolites for the MHR populations in both experiments were a putative glutathione-SA3 conjugate (and its amino acid catabolites). Overall, this research reveals that resistance to SA3 in these MHR waterhemp populations is due to enhanced metabolism, despite not having been previously exposed to this herbicide. SA3 metabolism in waterhemp is complex and diverges from the currently known routes of metabolism for HPPD-inhibiting herbicides. Future studies will directly investigate the possible metabolic enzymes involved in SA3 detoxification reactions using *in vitro* assays.

Herbicide-Resistance In Waterhemp (*Amaranthus tuberculatus*) Identified in Israel is Due to a Long Distance Gene Transfer. Inon Yadid, Aviv Zinger, Zvi Peleg, Baruch Rubin*; Hebrew University of Jerusalem, Rehovot, Israel (204)

Amaranthus tuberculatus var rudis (AT) is a summer annual alien dioecious weed that due to its vigor and prolific seed production causes severe yield loses to many crops. The weed invaded Israel ~ 20 years ago mostly infesting roadsides, but has been recently found in irrigated crops. The aims of this research were to map AT distribution across Israel and characterize its response to several herbicide mode of actions. In this survey, 30 AT populations were collected throughout Israel, indicating three main regions where the weed has been recorded: The Hula Valley, in Jezreel Valley along the Kishon river and the Coastal Plain along the Sorek river. Herbicide resistance was detected mainly in populations from the Jezreel Valley, while all population collected along the Sorek river were sensitive. Molecular studies have shown that four populations were identified as resistant to trifloxysulfuron, foramsulfuron and pyrithiobac-sodium as compared to the sensitive Tzora plants due to a Trp574Leu mutation, that endows a strong resistance to all ALS inhibitors. In addition, three PPO-resistant populations from the Jezreel Valley and Hula Valley were identified as putative resistant to carfentrazone-ethyl as compared to the susceptible Tzora population. The PPX2 gene (the target site of PPO) was sequenced in limited number of populations, and so far, no mutation was found in the resistant population. Since it is unlikely that AT populations were exposed in Israel to high or/and frequent herbicide applications, we assume that multiple events of overseas gene transfer have occurred throughout the years, most likely with animal feed shipments to Israel from the USA.

Distinct Metabolic Mechanisms for Tolerance and Resistance to *S*-Metolachlor in Corn and Two Illinois Waterhemp (*Amaranthus tuberculatus*) Populations. Seth Strom*[1], Aaron Hager[1], Adam Davis[1], Shiv S. Kaundun[2], Dean E. Riechers[1]; [1]University of Illinois, Urbana, IL, [2]Syngenta, Bracknell, United Kingdom (205)

Two Illinois waterhemp (*Amaranthus tuberculatus*) populations (CHR, SIR) are resistant to very-long-chain fatty acid (VLCFA)-inhibiting herbicides. The mechanism of resistance to the VLCFA-inhibitor, *S*-metolachlor, is enhanced metabolism compared with sensitive populations. Moreover, CHR and SIR metabolized *S*-metolachlor at the same rate as corn, which is naturally tolerant due to glutathione *S*-transferase (GST)-mediated metabolism. Current experiments were designed to expand upon previous findings and directly investigate the metabolic enzymes involved in *S*-metolachlor resistance. GST assays compared specific activities from CHR, SIR, a sensitive waterhemp population (WUS), and corn utilizing radiolabeled *S*-metolachlor as a substrate. Specific activities for CHR and SIR where 1.7–2.0 fold greater than WUS, respectively. Corn, however, possessed 2.6–3.0 fold greater GST activity than resistant waterhemp. P450 activity assays using waterhemp and corn microsomes were developed since CHR and SIR seedlings metabolize *S*-metolachlor as rapidly as corn, but do not have comparable GST activity. Microsomes from CHR and SIR possessed 21–28 fold greater specific activity than WUS using radiolabeled *S*-metolachlor as a substrate. CHR and SIR microsomes oxidized *S*-metolachlor 30–39 fold more efficiently than corn and formed a single metabolite, later identified as *O*-demethylated *S*-metolachlor via co-chromatography with an authentic standard and liquid chromatography-mass spectrometry. Results demonstrate CHR and SIR have enhanced GST activity and greater *S*-metolachlor *O*-demethylation activity than WUS or corn. Overall, metabolic resistance to *S*-metolachlor in CHR and SIR involves both GST-mediated and oxidative processes, but initial formation of *O*-demethylated *S*-metolachlor is the predominant mechanism. Research is underway to investigate the metabolomes and transcriptomes of resistant waterhemp to further explore the intricacies of metabolic *S*-metolachlor resistance.

Suppressing Herbicide-Resistant *Amaranthus* Populations by Inhibiting Reproduction.

Efrat Lidor Nili*[1], Ido Shwartz[1], Herve Huet[1], Miriam Aminia[1], A Stanley Culpepper[2], Micheal D. Owen[3], Orly Noivirt-Brik[1]; [1]WeedOUT, Ness Ziona, Israel, [2]University of Georgia, Tifton, GA, [3]Affiliation Not Specified, Ames, IA (206)

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.

"Pesticide Spray Drift and Non-Target Impacts"

Spray Drift of Florpyrauxifen-Benzyl from Ground Spray Equipment and Agricultural Aircraft. Thomas R. Butts*[1], Tom Barber[1], Jason K. Norsworthy[2], W Jeremy Ross[1], Gus M. Lorenz[3], John J. Adamczyk[4]; [1]University of Arkansas System Division of Agriculture, Lonoke, AR, [2]University of Arkansas, Fayetteville, AR, [3]University of Arkansas, Lonoke, AR, [4]USDA-ARS, West Poplarville, MS (207)

Florpyrauxifen-benzyl is a synthetic auxin herbicide used to control broadleaf, sedge, and grass weeds in rice (*Oryza sativa* L.). Off-target synthetic auxin movement has severe negative growth and reproductive impacts on susceptible crops such as soybean (*Glycine max* L. Merr.) and may subsequently impact pollinator foraging habits. With the prevalence of both ground and aerial herbicide applications in Arkansas, the objectives of this research were to compare the downwind deposition of florpyrauxifen-benzyl spray drift from both application methods and evaluate its impact on soybean growth and reproductive structures. A spray drift field study was conducted in October 2020 near Stuttgart, AR. Spray drift collection stations were equipped with one 76.2 x 50.8 mm water sensitive card, one 101.6 x 101.6 mm plastic Mylar card, and a soybean plant (V2 growth stage) as a bioindicator. A tank-mixture of florpyrauxifen-benzyl (29.4 g ai ha^{-1}) plus methylated seed oil (0.6 L ha^{-1}) plus 1,3,6,8-pyrene tetrasulfonic acid tetrasodium salt (PTSA dye, 2 ppm) was applied in 93.5 L ha^{-1} from a Case 5550 AimPoint commercial ground sprayer and 70.2 L ha^{-1} from an Air Tractor 802A agricultural aircraft. Ten separate passes for each sprayer were made providing 10 replicates. Following the application, soybean plants were grown in a greenhouse and visually assessed weekly for injury. At 35 days after application, flowers and pods were counted and plants were harvested for biomass measurements. Downwind deposition from the ground sprayer measured using the Mylar and water sensitive cards dissipated steeply in the first 10 m and reached a detectable limit at about 15 m downwind. Conversely, deposition from the agricultural aircraft had a flatter curve and never reached a detectable limit out to 61 m downwind. Soybean injury was first visible within three days following the application. All three soybean injury assessments (visual estimates of injury, reduction in reproductive structures, and biomass reduction) demonstrated 50% injury approximately 25 m downwind from the ground sprayer application. In contrast, soybean injury was approximately 75% at the farthest downwind collection station (61 m) from the aerial application. Across all data, the aerial application resulted in approximately 3- to 6-fold greater downwind spray drift than the ground application. This research provides insight into the spray drift potential of florpyrauxifen-benzyl from both ground and aerial spray equipment and demonstrates the potential influence off-target herbicide movement may have on pollinator foraging sources with the observed reduction in soybean reproductive structures.

2,4-D Drift Delays Hazelnut Abscission. Marcelo L. Moretti*, Larissa Larocca De Souza; Oregon State University, Corvallis, OR (208)

2,4-D is commonly used to control hazelnut suckers. However, the use of 2,4-D in sucker control was surmised to delay the natural abscission of the nuts. Hazelnuts naturally abscise and are collected from the orchard floor. Delays in abscission may reduce nut quality because of the onset of the rainy season, increasing mold and mud in the nuts. A longer-term field experiment was begun in 2018 to assess the impact of 2,4-D on nut abscission. Treatments, applied in 2018, 2019, and 2020, included four applications of 2,4-D at 1.1, 2.2, and 4.4 kg ai ha^{-1}, glufosinate at 1.1 kg ai ha^{-1} and a nontreated control. Treatments were directed to the suckers. A simulated drift of 2,4-D at 0.01 and 0.1 kg ai ha^{-1} were applied to the tree canopy in the summer of 2018 and 2019, but not in 2020. Hazelnut abscission was monitored twice weekly by counting the presence of selected nuts and by harvesting all nuts on the floor. Binomial logistic and non-linear regression analyses were used to estimate the time to 50% nut abscission. The simulated drift of 2,4-D delayed hazelnut abscission in 2018 and 2019. Trees receiving 2,4-D drift were 2 to 11 times more likely not to abscise nuts compared to trees not receiving drift in 2018 and 2019. The time required to abscise 50% of nuts was five days greater in simulated drift with 2,4-D 0.1 kg ai ha^{-1} as compared to the nontreated control. No differences in abscission timing were observed in 2020. Simulated drift at the highest rate reduced yield by 0%, 36%, and 30% in 2018, 2019, and 2020 respectively. These data indicate that 2,4-D drift can delay nut abscission, highlighting the importance of drift control measures.

Effect of Simulated Herbicide Drift on Agronomic Crops. Ronald R. Rogers*, Travis Gannon, Patrick J. Maxwell, Daniel Freund, Shwetha S. Ramanathan, Mathieu LeCompte; North Carolina State University, Raleigh, NC (209)

Studies were conducted to quantify corn (*Zea* mays L.) and soybean (*Glycine max* L.) response as affected by simulated herbicide drift at various timings. Seven herbicides (2,4-D + 2,4-DP-p, Clopyralid + triclopyr, Imazapic, Imazapyr, Metsulfuron-methyl, Sulfometuron-methyl and Triclopyr ester) were applied at four pre-plant timings and two post-plant timings with 1, 5, 10 and 100 % of a typical North Carolina roadside vegetation management rate. Above ground biomass was quantified. Synthetic auxin treatments contributed to the highest reduction of above ground biomass. At 4 WAP triclopyr ester applied at 1, 5 and 10 % rates reduced soybean aboveground biomass from 42.1-98.9%. Sulfometuron proved to be the most detrimental herbicide to corn above ground biomass when applied at 1, 5 and 10 % rates for PRE and at timings.

Assessment of Triclopyr Non-Target Injury to Native Shrubs Following Basal Bark Treatment. Stephen F. Enloe*, Conrad Oberweger; University of Florida, Gainesville, FL (210)

Triclopyr is widely used for basal bark treatment of woody invasive species in uplands and seasonally dry wetlands. However, the butoxyethyl ester formulation used for basal bark treatment is limited in wetlands during the summer by high water levels. Recently, a new acid formulation of triclopyr was labeled for use in wetlands and aquatic sites and this has resulted in expanded use of basal bark treatment when standing water is present. However, a few cases of apparent triclopyr flashback in wetlands have prompted a need to understand how the herbicide is reaching surrounding nontarget species when applied as the new acid formulation. To address this, two mesocosm studies were conducted to examine potential triclopyr movement to nontarget species under differing hydrologic scenarios. The invasive shrub *Schinus terebinthifolia* (target species) and three native shrubs, *Cephalanthus occidentalis*, *Acer rubrum*, and *Celtis laevigata* (non-target species) were established in 94-liter tubs filled with builder's sand. In the first study, activated charcoal was applied to the sand prior to basal bark treatment to isolate the potential for triclopyr root exudation from the treated species. In the second study, a flooding treatment was applied post basal bark treatment to examine the potential release of triclopyr from the root collar of treated stems into surface water. For both studies, leaf counts, live cambium heights and visual estimates of defoliation and injury for all four shrub species were collected over an eight-week period following treatment. Additionally, water samples were collected weekly for triclopyr analysis from wells in each tub and additionally from surface water in the flooding study. In both studies, basal bark treatment resulted in >97% defoliation of *Schinus terebinthifolia* by eight weeks after treatment. In study 1, there was no evidence for triclopyr injury on any of the non-targets through possible root exudation of triclopyr from the treated shrub. In study 2, there was limited evidence for triclopyr injury on *Acer rubrum* when treated plants were subsequently flooded. Triclopyr analysis in the water samples has been delayed due to COVID-19. These initial studies provide evidence for potential triclopyr injury when flooding occurs. Subsequent triclopyr analysis from the water samples will clarify this issue and help inform invasive plant managers on best management practices for basal bark treatment with the acid formulation.

“Science Policy Fellow Report”

The Intersection of Weed Science and Politics: What We Learned During Our Virtual Science Policy Fellowships. Vasiliy T. Lakoba*[1], Lavesta C. Hand[2], Lee Van Wychen[3]; [1]Virginia Tech, Blacksburg, VA, [2]University of Georgia, Tifton, GA, [3]Weed Science Society of America, Alexandria, VA (211)

Weed scientists strive to educate stakeholders and the general public about the impact of weeds in managed and natural ecosystems. Policy makers and elected government officials can have a large influence on the allocation and regulation of resources to research and manage weeds. One of the main goals of WSSA's Science Policy Committee is to make the expertise of the national and regional weed science societies known and readily available to Congress, Federal Agencies, non-governmental organizations (NGO's), and other scientific societies. Young weed scientists often lack exposure and experience with the federal science policy process. The WSSA Science Policy Fellowship provides a unique opportunity for graduate students to assist the Executive Director of Science Policy, Dr. Lee Van Wychen, while gaining experience with weed science policy issues. This past year, Vasiliy Lakoba and Camp Hand were able to participate in numerous weed science policy activities such as analyzing results from the national survey for the most common and troublesome weeds and helping plan National Invasive Species Awareness Week. Due to COVID-19, all experiences were virtual. As Science Policy Fellows, they represented WSSA by drafting comments on important rules and regulations such as EPA's proposed interim decision for paraquat and draft biological evaluations for the triazines and glyphosate that are going through reviews for the Endangered Species Act. Vasiliy and Camp have also drafted comments for the Department of Interior's Invasive Species Strategic Plan and USDA's Ag Innovation Agenda, among others. They were able to participate in meetings with congressional staff from Virginia, Louisiana, Montana, Pennsylvania, Iowa, Georgia, Utah, Indiana, Minnesota, and North Carolina along with the weed science and aquatic plant management society presidents to discuss pertinent issues facing weed science. During this fellowship, Vasiliy and Camp learned about the importance of advocating for weed science and the funding opportunities available to weed scientists. The fellowship provided them with a unique opportunity to experience a broad array of weed science policy issues and better understand the intricacies of science policymaking at the federal level.

"Using Cover Crops for Weed Management"

Weed Control and Herbicide Tolerance of Establishing White Clover (*Trifolium repens*) as a Living Mulch. Nicholas T. Basinger*, Nicholas S. Hill; University of Georgia, Athens, GA (212)

With the increasing focus on herbicide-resistant weeds and loss of herbicides due to regulations, many producers have turned to annual cover crops as a tool for reducing weed populations. Recent studies have suggested that perennial cover crops such as white clover could be used as a living mulch. White clover is slow to establish and is susceptible to competition from winter weeds such as wild radish. Studies were conducted in the fall and winter of 2018-19 and 2019-20 at the J. Phil Campbell Farm in Watkinsville, GA, and the Southeast Georgia Research and Education Center in Midville, GA to evaluate clover tolerance and weed control. POST applications of imazethapyr (70 g ai ha^{-1}), bentazon (840.6 g ai ha^{-1}) flumetsulam at low and high rates (30g ai ha^{-1}; 60 g ai ha^{-1}), or combinations in combination with 2,4-D (105 g ai ha^{-1}) and 2,4-DB (1492 g ai ha^{-1}), were applied when clover reached 2 to 3 trifoliate stage. Six weeks after the early POST, a sequential application of bentazon (840.6 g ai ha^{-1}), flumetsulam alone (30 g ai ha^{-1}) and combinations of 2,4-D (105 g ai ha^{-1}), 2,4-DB (1492 g ai ha^{-1}), and flumetsulam (30 g ai ha^{-1}) were applied over designated plots. Clover biomass was similar across all treatments except where it was reduced by sequential applications of 2,4-D + 2,4-DB + flumetsulam in 2019-2020, indicating that most treatments were safe for use on establishing living mulch clover. A single application of flumetsulam at the low rate (30 g ai ha^{-1}) provided the >90% control of wild radish. A single application of 2,4-D + 2,4-DB, or sequential applications of Bentazon also provided >90% control and could be used if rotation restrictions prevented the use of flumetsulam.

Multi-Species and Intensified Cover Crops for California Nut Tree Orchards. Steven C. Haring*[1], Brad Hanson[2]; [1]University of California - Davis, Davis, CA, [2]University of California - Davis, Winters, CA (213)

Cover crops are useful for adding biodiversity to cropping systems that can provide a variety of ecosystem services, including weed suppression. Orchard cover crops in California are currently implemented as winter plants growing on orchard floor alleyways. More specific management recommendations are required to optimize the weed suppression ability of these cover crops. We designed two separate, small-plot experiments to understand which management factors are most important for orchard cover crops. The first experiment involved two five-species mixes of cover crops, including a mustard-based mix and a mustard-grass-legume mix, each planted at two different planting dates, a late-fall planting date in October of each study year and a mid-winter planting date in January or February of each study year, in a young almond orchard. Vegetation was monitored using weekly point-intercept transects before cover crop and weed biomass were destructively sampled at cover crop termination in April 2019 and 2020. The second experiment involved cover crops grown across a range of management intensities in a mature walnut orchard. Cereal rye (*Secale cereale* L.) was the main component of the programs, which included a low-input cover crop, a 'boosted' cover crop with additional fertilizer and starter irrigation, a similar mustard-grass-legume mix as described above, and a forage intercrop. These four management programs, as well as a standard, herbicide-based program, were installed in November 2019, and cover crops were terminated in April 2020. Cover crop and weed biomass were destructively sampled at cover crop termination. Results from these experiments suggest that orchard cover crops can be useful for displacing winter weeds across a variety of management programs, but weeds were always present within cover crops to some degree. Timely cover crop planting helps cover crops emerge ahead of weeds and can facilitate an abundant cover crop in the absence of other vegetation management options. Continuation of these experiments will help us understand cumulative effects of cover cropping, including weed community shifts. Future research will help explain the tradeoffs between a competitive cover crop and long-term effects on orchards, as well as provide insight into the mechanisms of competition between cover crops and weedy plants.

Using Weed-Suppressive Corn and Cover Crops for Weed Management and Increased Profitability of Corn. Rachel Nobles*[1], Gracen A. Fuller[2], W. Brien Henry[1], Te-Ming (Paul) Tseng[1]; [1]Mississippi State University, Mississippi State, MS, [2]Mississippi State University, Starkville, MS (214)

Corn plays a major role in crop production in the state of Mississippi. Weeds prove to be the primary threat to corn production. Morningglory is a weed that winds around plants, eventually suffocating the corn crop. Traditional pesticides have proved to be ineffective in controlling the weed throughout the duration of the corn growing season. Additionally, the heavy usage of chemicals for weed control may result in herbicide-resistant weeds, which tends to complicate crop management. Among the tools in integrated weed management are the use of weed-suppressive/competitive cultivars to minimize weed competition. The natural consequence of this is the reduced need for herbicide application and increased herbicide efficacy because of the reduced weed population. Maximum herbicide rates or multiple herbicide applications may no longer be needed, which is good for the environment. The selection of weed suppressive corn varieties in a modified stair-step assay was utilized in this research. Three repetitions of ten corn varieties were tested in the stair-step system. The height, chlorophyll concentration, as well as biomass, was measured and recorded for every plant. Three weed-suppressive corn varieties, DKC, Slow Food #2, and Long #2, were identified that reduced morningglory height by 30-53%. DKC70-27 was the best performing variety that resulted in a 53% reduction in morningglory plant height. We hope to screen additional varieties against additional weed species and confirm the results in a field study.

Evaluating Cover Crop Termination Timing on Cover Crop Biomass, Weed Suppression, and Ultimate Yield Goal Outcome. Cynthia Sias*, Michael L. Flessner, Kevin W. Bamber; Virginia Tech, Blacksburg, VA (215)

Appropriate termination of the cover crop is essential for successful weed control throughout the season. Often times, termination of the cover crop is dictated by planting time windows and chemical applications. Adequate timing of termination is needed to allow for appropriate crop seed establishment while still reducing weed competition. Research evaluated the effect of multiple termination timings of winter wheat and rye by terminating the cover crop at 4 and 2 weeks before planting, 2 and 4 weeks after planting and at the time of planting. This experiment was conducted at 3 different locations in Virginia during 2019-2020, with each location as a randomized complete block design with four replications per treatment. Total biomass and weed suppression data were collected for each of these trial locations and years. Data were subjected to a 3 parameter regression using JMP to evaluate the observed changes in cover crop biomass over time. While the data shows that termination timing was not significant for total biomass accumulations, the interaction between treatment and site year was significant. This information is useful for farmers trying to decide when to terminate to achieve high cover crop biomass production and achieve maximum weed control. Future research is ongoing to investigate how these findings are then applied to rolled vs. standing cover crops.

Evaluation of Cover Crop, Herbicide, and Tillage Combinations for Integrated Weed Management. Kurt M. Vollmer*[1], Mark VanGessel[2], Barbara A. Scott[2], Quintin R. Johnson[2]; [1]University of Maryland, Queenstown, MD, [2]University of Delaware, Georgetown, DE (216)

Integrated strategies are an important tool for weed control. A 3-year study was conducted to evaluate the effects of integrating mechanical, cultural, and chemical weed control systems in corn and soybean. The study was a 4-factor split plot with four replications. The whole plot consisted of tillage system (1-time fall moldboard plow [year 1], spring tillage each year, or no-till). Subplots consisting of crop rotation (corn-soy-corn or soy-corn-soy), cover crop (with fall seeded or without), and PRE herbicide treatment (with or without). Cover crops were 34 kg ha^{-1} cereal rye + 34 kg ha^{-1} hairy vetch prior to corn planting, and 135 kg ha^{-1} cereal rye prior to soybean planting. PRE herbicide treatments were 1.8 kg ha^{-1} atrazine + 1.4 kg ha^{-1} *S*-metolachlor in corn, and 0.07 kg ha^{-1} flumioxazin + 0.13 kg ha^{-1} pyroxasulfone in soybean. Cereal rye + hairy vetch biomass at termination ranged from 250 kg ha^{-1} to 1,317 kg ha^{-1} prior to corn planting, and cereal rye biomass at termination ranged from 1,200 kg ha^{-1} to 4,910 kg ha^{-1} prior to soybean planting. Cover crops reduced winter annual weed biomass by 76% compared to no cover, regardless of cropping system. Following 3 years of crop rotation, Palmer amaranth density was 97% lower when PRE herbicides were included, regardless of crop rotation, cover crop, or tillage system. However, when PRE herbicides were not included, Palmer amaranth density was 82% lower in no-till and fall moldboard plots compared to spring-tilled plots, and 27% lower in the corn-soy-corn rotation compared to the soy-corn-soy rotation. By year 3, common ragweed density was 93% lower in no-till and fall moldboard plots compared to spring-till plots in the corn-soy-corn rotation. These results demonstrate that cultural, mechanical, and chemical tactics can be incorporated for successful management of both winter and summer annual weeds.

Using Soil Steaming and Cover-Crops for Weed Management and Increased Profitability of Organic Tomato Production. Sydney Stockwell*[1], Shandrea D. Stallworth[1], Isabel S. Werle[1], Clay Cheroni[2], Shaun R. Broderick[2], Te-Ming (Paul) Tseng[1]; [1]Mississippi State University, Mississippi State, MS, [2]Mississippi State University, Crystal Springs, MS (217)

Weed suppression is a growing problem in the tomato production industry. Weeds such as yellow and purple nutsedge, large crabgrass, and Palmer amaranth contribute to the largest yield losses in tomato. This study aimed to explore the effectiveness of cover crops and soil steaming as methods of weed management in organic tomato production. These experiments were conducted at the Mississippi Agricultural and Forestry Experiment Station's Truck Crops Branch (MAFES Truck Crops Branch) in Crystal Springs, MS. A randomized split-plot experimental design was used, consisting of six treatments and three high-tunnel replications. A mixture of yellow nutsedge, large crabgrass, and Palmer amaranth was sown into each plot at 20 plants m^{-2}. Two days later, each plot was steamed at a temperature of approximately 82şC for treatments of either 0, 5, or 20 minutes. Weed cover, plant height, and fruit yield were monitored. The highest percent of weed coverage was found in treatments with 0 minutes of soil steaming, recording 55% weed coverage consisting mostly of yellow nutsedge. The difference in plant heights between mulched treatments versus non-mulched was 8 cm on average and about 5 cm in steamed (5 or 20 minutes) versus non-steamed treatments. Mulching and soil steaming treatments (5 and 20 minutes) resulted in a 46 and 57% increase, respectively, in total crop yield. This study primarily shows that soil steaming-- even as little as five minutes-- is an effective method of weed suppression in commercial tomato production, successfully providing a more sustainable and environmentally safe method of weed control.

"Management Strategies for Invasive Plants"

INHABIT: a Web Application to Deliver Habitat Suitability Models and Bridge the Scientist-Practitioner Divide. Peder S. Engelstad*[1], Catherine Jarnevich[2], Terri Hogan[3], Helen Sofaer[4], Ian Pearse[2], Jennifer Sieracki[3], Nicholas E. Young[1], Janet Prevey[2], Jillian LaRoe[2], Pairsa Belmaric[2]; [1]Colorado State University, Fort Collins, CO, [2]U.S. Geological Survey, Fort Collins Science Center, Fort Collins, CO, [3]National Park Service, Fort Collins, CO, [4]U.S. Geological Survey, Pacific Island Ecosystems Science Center, Hawaii National Park, HI (218)

Many practitioners are hampered by the scope of the invasive species problem compared to available resources that combat invasive species. Habitat suitability models for invasive species can provide practitioners with information to advise watch lists and target population searches. While many suitability models exist, there is often a divide between researchers creating these models and practitioners who may find them useful in informing land management actions. We have formed a scientist-practitioner partnership to create national models for priority species that are integrated into the Invasive Species Habitat Tool (INHABIT), a web application displaying visual and statistical summaries of nationwide habitat suitability models. The models are based on aggregated occurrence data and a species-specific set of predictors from a library of environmental predictors we have assembled. The models are built following a common protocol, promoting model repeatability and credibility. Managers provide feedback both on the models and INHABIT's features, iteratively improving the content and functionality of INHABIT. This app is designed to provide practical information leading to enhanced land management actions, including mapped products with interactive thresholds to define suitability based on management objectives (with field-device compatible download options), information on modeled environmental relationships, and tabular proximity summaries to inform management area watch lists. Based on comments and suggestions of practitioners, INHABIT is actively evolving to help bridge the gap between scientists and practitioners.

Niche Dynamics of a Global Invader. Vasiliy T. Lakoba*[1], Daniel Z. Atwater[2], Jacob Barney[1]; [1]Virginia Tech, Blacksburg, VA, [2]Earlham College, Richmond, IN (219)

Species niches have been defined in different ways, variably encompassing abiotic and biotic parameters limiting an organism's spatial distribution. Climate is often the main component of the abiotic (fundamental) niche, especially among terrestrial plants. In invasion biology, there is an ongoing debate on the prevalence of niche shifts, which may be linked to divergent traits in a species' native and invaded ranges. We used a large dataset to test whether shifts can be seen in the invader Johnsongrass (*Sorghum halepense*), which has undergone intercontinental spread as well as habitat-switching and local adaptation within its invaded range of North America. Climate space ordination showed that while North America is, on average, colder and wetter than the other continents combined, North American Johnsongrass occupies warmer and drier habitats than in the rest of the world. We found no such disagreement between niche availability and occupancy in the transition from agricultural to non-agricultural ecotypes in North America, with both shifting toward colder climates. Notably, while non-agricultural populations far outnumber agricultural ones, the former occupy a narrower niche ($D_M = 15 \pm 0.4$) than the latter ($D_M = 21.5 \pm 1.2$), implying agriculture's role in providing suitable habitat in otherwise suboptimal climates. Our maximum entropy models of agricultural and non-agricultural North American populations showed very limited ecotypic differences in current suitability or range expansion under climate change through the rest of this century. We also predicted climatic suitability for Johnsongrass to increase most in the Upper Midwest and Great Plains by 2100. These results help us contextualize the body of empirical evidence for ecotypic differentiation in Johnsongrass, as well as make predictions about future range expansion and potential damage niches.

Evaluating the Impact of Timed Hexazinone Applications on Brunswickgrass. Clay Cooper*[1], Brent A. Sellers[2]; [1]University of Florida, Lecanto, FL, [2]University of Florida, Ona, FL (220)

Brunswickgrass (*Paspalum nicorae* Parodi), sometimes referred to as "brown-seeded paspalum", is a problematic weed in summer perennial grass pastures in the southeast. In Florida we have seen increasing pressure to control this weed contaminate as it is becoming a major threat to livestock and bahiagrass seed industries. This rhizomatous grass is refused by cattle and seed could potentially restrict sales of contaminated bahiagrass seed lots. Currently, management options are limited; therefore, the objective of this research is to develop a management plan for Brunswickgrass in Bahiagrass seed production fields. Two experiments are currently underway with one being a continuation of a two-year titration study and the other focusing on application timing. Experiments were established within Citrus and Sumter in 2018 to address Brunswickgrass response to the application of hexazinone at 0.14, 0.28, 0.56, 0.84, and 1.12 kg ai ha-1 . In 2019, an application timing study was established assessing control differences between month and rate. Applications were made monthly starting in May until September at rates of 0.56, 0.84, and 1.12 kg ai ha^{-1}. In the titration study, hexazinone appears to have significant activity with all rates of hexazinone resulting in at least 44% control 30 days after treatment (DAT). Hexazinone at rates of at least 0.84 kg ha^{-1} resulted in at least 97% control 30 DAT. By 365 DAT there was no difference among treatments and control ranged from 0 to 60%; seedling recruitment is the likely cause of the increase in Brunswickgrass. A second application onto the same plots resulted in at least 80% Brunswickgrass control across all hexazinone rates, and rates of 0.28 kg ha^{-1} resulted in at least 93% control 30 DAT. By 365 DAT of the second hexazinone application, control ranged from 40 to 96% across all hexazinone treatments; only 1.12 kg ha^{-1} resulted in >90% control. There was no rate by month interaction at 30 or 365 DAT in the timing study, however, both month and rate were significant. Hexazinone at 0.56, 0.84, and 1.12 resulted in 81, 85, and 95% control at 30 DAT. Application of hexazinone in May resulted in the lowest level of control (63%), but all other application timings resulted in control of at least 86%. At 365 DAT, 0.56 kg ha^{-1} resulted in 56% control, and at least 74% control was achieved with the higher rates. Similar to 30 DAT, the May application timing resulted in the lowest level of control by 365 DAT (34%), whereas all other timings resulted in similar levels of control of at least 71%. Overall, these results are promising in the fact that we are seeing some initial success using hexazinone for Brunswickgrass management. However, it is evident that multiple annual applications may be necessary to deplete the soil seed bank. Also, applications should not be made prior to June for optimal activity.

“Latest Technologies for Weed Management”

Influence of Sodium Cation and Various AMS Adjuvants on the Performance of Various Glyphosate Formulations. Gregory K. Dahl*[1], David A. Van Dam[2], Martin M. Carr[2], Amanda Flipp[3], Laura J. Hennemann[3], Joshua J. Skelton[4]; [1]Winfield United, Eagan, MN, [2]Winfield United Canada, Saskatoon, SK, Canada, [3]Winfield United, River Falls, WI, [4]WinField United, Saint Paul, MN (238)

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.

Smooth Scouringrush (*Equisetum laevigatum*) Control with Glyphosate is Affected by Surfactant, Rate, and Timing. Mark E. Thorne*, Drew J. Lyon; Washington State University, Pullman, WA (239)

Smooth scouringrush (*Equisetum laevigatum*) is a deep-rooted perennial that has spread into cropland in eastern Washington during the last twenty years with the adoption of no-till practices and chemical fallow. Glyphosate has been extensively used for weed management in chemical fallow, but applications have failed to control smooth scouringrush at rates targeted to control annual weeds. Smooth scouringrush stems contain a high concentration of silica, which may inhibit herbicide movement through the epidermis. We applied high rates of glyphosate to smooth scouringrush stems in fallow, with either a rope wick applicator (404 g ae L^{-1}) or broadcast sprayer (3783 g ae ha^{-1}) in two preliminary trials initiated in 2018. Sites were near Omak and Reardan, WA with Omak treatments applied five weeks prior to Reardan. At Reardan, we added a glyphosate plus an organosilicone surfactant (0.25% v v^{-1}) treatment. Experimental design was a randomized complete block with four replications per treatment. Glyphosate through a rope wick reduced stem density in the following winter wheat crop by 78% and 63% compared to nontreated check plots at Omak and Reardan, respectively. Glyphosate alone, applied at Omak, was more effective than glyphosate alone applied at Reardan. Glyphosate plus an organosilicone surfactant at Reardan resulted in the lowest biomass in the following winter wheat crop but was not different from the rope wick treatment. We initiated a study in 2019 comparing glyphosate, glyphosate plus an organosilicone surfactant, and no glyphosate, at the same rates as above, at three locations in eastern Washington and at four times starting in late May and ending in late August. Treatments were applied in chemical fallow and experimental design was a split-plot randomized complete block with four replications per main-plot treatment. Timing of application was randomized across main plots, and herbicide treatments were randomized within each main plot. Broadcast applications of glyphosate with the organosilicone surfactant were consistently more effective than glyphosate alone in reducing stem density in the following winter wheat crop but differed some by location and application timing. The organosilicone surfactant may have increased glyphosate movement through the smooth scouringrush epidermis, but more likely facilitated uptake through open stomates.
mthorne@wsu.edu

Precision See & Spray™ - Enabling New Opportunities for Weed Management. William L. Patzoldt*; Blue River Technology, Sunnyvale, CA (240)

Deep learning is an emerging subfield of artificial intelligence that allows computers to teach themselves how to solve problems. When deep learning models are deployed on intelligent sprayers capable of precision applications (e.g., See & Spray™), the combination creates novel opportunities to control herbicide-resistant weeds. Results from a 2019 field trial in cotton (*Gossypium hirsutum*) with a known population of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) suggested precision applications of paraquat plus prometryn, together with broadcast applications of glyphosate plus acetochlor, provided greater control when combined in the same treatment pass than the same applications in separate treatments. With this information in mind, the objective of a field trial in 2020 was to continue the evaluation of precision applications combined with different broadcast partners, but also include programs that could be used with conventional cotton varieties (i.e., not containing herbicide resistance traits). POST program treatments in 2020 were preceded by either a 1X or 0.5X rate of a PRE herbicide program using *s*-metolachlor at 1070 g ai ha^{-1} plus fluometuron at 840 g ai ha^{-1} (designated as the 1X rate) to create different weed densities and applied one day after planting. Treatments with a two-POST pass herbicide program were applied 25 and 43 days after planting. The precision See & Spray herbicide POST programs consisted of paraquat at 560 g ai ha^{-1} plus prometryn at 730 g ai ha^{-1} *fb* paraquat at 560 g ai ha^{-1} plus prometryn at 730 g ai ha^{-1}. Broadcast partners were applied using a separate boom, but at the same time as precision applications, and included either 1) glyphosate at 870 g ae ha^{-1} with or without *s*-metolachlor at 1420 g ai ha^{-1} *fb* glyphosate at 870 g ae ha^{-1} (glyphosate program) or 2) pyrithiobac at 73 g ai ha^{-1} plus quizalofop-*p*-ethyl at 62 g ai ha^{-1} with or without *s*-metolachlor at 1420 g ai ha^{-1} *fb* quizalofop-*p*-ethyl at 62 g ai ha^{-1} (conventional program). Precision See & Spray herbicide programs were compared with either 1) glyphosate at 870 g ae ha^{-1} *fb* glyphosate at 870 g ae ha^{-1} (negative control) or 2) dicamba at 560 g ae ha^{-1} plus glyphosate at 870 g ae ha^{-1} plus *s*-metolachlor at 1420 g ai ha^{-1} *fb* dicamba at 560 g ae ha^{-1} plus glyphosate at 870 g ae ha^{-1} (positive control). Significant visual cotton injury >5% was observed with several treatments, but this could be attributed to pyrithiobac and/or *s*-metolachlor products and not precision See & Spray. Regarding glyphosate-resistant Palmer amaranth control, only the glyphosate *fb* glyphosate program (negative control) preceded by the 0.5X PRE rate had significantly reduced control at 73% when compared with the positive control treatment receiving 100% control at 34 DAT. All precision See & Spray programs provided >98% visual Palmer amaranth control when preceded by either the 1X or 0.5X PRE rates at 34 DAT and equivalent to the positive control (P=0.1, N=4). Herbicide program input costs were estimated using the least expensive online sources for both the herbicide products and adjuvants, and then adjusted based on percent area treated. The total herbicide program input costs for the positive control program (dicamba plus glyphosate program) ranged between \$131 to \$146 ha^{-1}; whereas the precision See & Spray plus glyphosate or conventional programs ranged between \$54 to \$69 ha^{-1} or \$71 to \$81 ha^{-1}, respectively. Cotton lint yield data was also collected in the trial and all precision See & Spray programs provided equivalent weed control to both the herbicide positive control and hand-weeded checks. While the glyphosate *fb* glyphosate negative control treatment preceded by the 0.5X PRE rate did have significantly reduced visual Palmer amaranth control, lint yield was not significantly reduced at 1,221 kg ha^{-1} when compared with the positive control at 1371 kg ha^{-1}. The lint yield of the precision See & Spray plus glyphosate program (without *s*-metolachlor) was 1,328 kg ha^{-1}, which represents a 107 kg ha^{-1} increase in yield compared with the broadcast applications of glyphosate alone, which translates to an additional $170 per ha^{-1} at current prices. Collectively, data from this study suggests precision See & Spray applications can reduce herbicide input costs by ~50% and provide increased yield protection against herbicide-resistant weed competition. In summary, deep learning enabled precision See & Spray applications could be used to combat herbicide-resistant weeds, reduce weed control input costs, and provide new opportunities for producers using conventional crop varieties.

Efficacy of a Precision Herbicide Applicator for Row Middles in Plasticulture Production Systems. Ravneet K. Sandhu*[1], Nathan Boyd[2], Arnold W. Schumann[3], Shaun M. Sharpe[4]; [1]University of Florida, Wimauama, FL, [2]University of Florida, Balm, FL, [3]University of Florida, Lake Alfred, FL, [4]Agriculture and Agri-Food Canada, Saskatoon, SK, Canada (241)

Florida small fruiting vegetables, particularly tomato and peppers, have struggled with control of row-middle weed growth due to increased herbicide resistance in weeds. Besides, the control of broadleaf weeds like nightshade is a critical concern since they are a secondary host for multiple tomato diseases. In comparison to broadcast application, precision delivery of the herbicides through remote sensing of weed plants application lowers costs by reducing inputs, drift concerns, and herbicide-treated sand blown onto the crops. The objective of the study was to determine the accuracy and efficacy of precision herbicide sprayer to detect and control broadleaf, nutsedge and grass weeds in row middles. Field experiment was done in Fall 2020 using natural weed population in row middles at Gulf Coast Research and Education Center, Balm, FL. Treatments included non-treated control, two banded applications (Pre- and post-herbicides) with conventional equipment and two precision application using smart sprayer. The first application was done after the fumigation and second application was done 21 days after first spray. The results of the study showed that weed detection accuracy of precision sprayer was around 75%, 68% and 7 % for broadleaf, nutsedge and grass weeds, respectively. At second spray, treatment with pre-emergence herbicide reduced spray volume by 46%, whereas in treatment with no pre-emergence herbicide application, volume was reduced by 15%. This signifies that initial pre-emergence herbicide application is very critical to overall herbicide use and weed control. However, there was no adequate weed control ($p>0.05$) was observed. The precision sprayer is viable and economical option for FL vegetable growers to control weeds in row-middles. However, there is need for selective herbicides and improved weed detection model training for effective weed control.

Deep Learning-Based Weed Recognition in Australian Ginger (*Zingiber officinale*) Production. Caleb Squires*[1], Guy Coleman[2], Michael J. Walsh[3]; [1]University of Sydney, Brownlow Hill, Australia, [2]University of Sydney, Camden, Australia, [3]University of Sydney, Narrabri, Australia (242)

Weed recognition using convolutional neural network-based semantic segmentation offers new opportunities in site-specific weed control, with improved ability to precisely deliver non-selective control options. Ginger (*Zingiber officinale*) is a specialty crop in Australia with few herbicides registered for selective in-crop weed control. A prototype three axis delivery system has been developed, but to enable deep learning-based weed recognition in ginger crops, 120 crop images from 5 ginger farms across New South Wales and Queensland Australia were manually labelled in a pixel-wise fashion. Synthetic data generation was then investigated as an alternative to the labor-intensive labeling procedure by creating a separate data set of 2000 annotated images developed using computer vision techniques. Each data set was used to train a separate algorithm using the DeepLab v3+ architecture with an Xception 65 backbone. The algorithms were tested for accuracy on an unseen subset of 14 images from across the five farms, with the intersection over union metric (IoU) reported for comparison. After 10,000 training steps the field data algorithm achieved an IoU of 0.40 for ginger plants, 0.18 for grass weeds, and 0.04 for broad-leaf weeds. The algorithm trained on the synthetic data performed similarly, achieving IoU of 0.36, 0.17, and 0.07 for ginger, grass weeds, and broad-leaf weeds, respectively. This approach suggests synthetic images provides useful supplementary training data for semantic segmentation algorithms, to reduce the reliance on the labor intense manual labeling process.

Introduction of the CPDA Application Enhancement Program. Joe V. Gednalske*[1], Susan Sun[2], Greg Kruger[3], Bradley K. Fritz[4], Jim Reiss[5]; [1]CPDA, River Falls, WI, [2]Croda Inc., New Castle, DE, [3]University of Nebraska - Lincoln, North Platte, NE, [4]USDA-ARS, College Station, TX, [5]Precision Lab, Waukegan, IL (243)

The reduction of off target movement of herbicides has been a desired goal of the EPA, the crop protection industry and weed scientists since the first herbicide applications were made. Our efforts have led us to larger and larger spray droplets to reduce drift, with the cost of reduction in performance of many herbicides. The balance between minimizing fine drops, without significant volumes of the spray being composed of droplets too large for optimal herbicide efficacy, is an achievable goal. This paper will discuss the program and testing process which can help applicators pick combinations of nozzles, drift reduction adjuvants and herbicide with optimized droplet sizing. We solicit the help of the WSSA members to assist in launching and refining this program.

“Physical & Mechanical Weed Control Tools”

Initial Impressions of the Redekop Seed Control Unit for Harvest Weed Seed Control.
Michael L. Flessner*[1], Steven Mirsky[2]; [1]Virginia Tech, Blacksburg, VA, [2]USDA-ARS, Beltsville, MD (244)

Harvest weed seed control (HWSC) targets weed seeds retained on the plant at harvest through various techniques that kill, concentrate, or remove weeds seeds with the harvest operation. The Redekop Seed Control Unit (SCU) is a seed impact mill, which is a form of HWSC. Seed impact mills attach to the rear of the combine and process chaff and weed seeds contained therein, prior to spreading the residue. Seed impact mills have been shown to be highly effective (>95% seed kill) on many key weed species. A SCU was installed on a John Deere S680 combine and used to harvest common ragweed (*Ambrosia artemisiifolia*) infested soybean fields in Northampton County, Virginia. One feature of the SCU is that it can be turned on or off, which was used to compare combine engine capacity, fuel use, and travel speed in 4 fields, as recorded from the combine's display. Soybean yield varied between fields but was less than 2,300 kg/ha (35 bu/a). Engine capacity increased in all fields when operating the SCU versus not, ranging from 12 to 36% with an average increase of 19.5%. Similarly, fuel use increased in all fields, from 7.6 to 19.7 L/hr (2.0 to 5.2 gal/hr) with an average increase of 13.1 L/hr (3.45 gal/hr). Despite an increase in engine load, travel speed of the combine was not reduced in any field, indicating that this class 8 combine (473 horsepower) had sufficient capacity to operate the SCU without slowing harvest. These fields and others will be tracked in long-term studies to evaluate HWSC with successive harvests and in crop rotations. Other ongoing research includes seed kill efficacy testing, weed seed fate in the combine, and how moisture affects these. While more research needs to be done, our initial impression of the SCU after one harvest, combined with previous research and experience with HWSC, indicate a strong potential for seed impact mill adoption in the US.

Phenological Shifts in Flowering Due to Selection Pressures of Harvest Weed Seed Control.

Lauren M. Lazaro*[1], Gabrielle LaBiche[1], Daniel O. Stephenson, IV[2], Josh T. Copes[3], Donnie Miller[4]; [1]Louisiana State University AgCenter, Baton Rouge, LA, [2]LSU Ag Center, Alexandria, LA, [3]LSU AgCenter, St. Joseph, LA, [4]Louisiana State University AgCenter, St. Joseph, LA (245)

Historically, management strategies have focused on short-term reduction of the most troublesome weeds in a field based on annual economic thresholds, without a specific focus on the long-term ramifications of soil seedbank management. Restricting the weed seedbank has a large impact on future population density and influences management practices of these weeds in soybean production systems. Harvest weed seed control (HWSC) tactics incorporate mechanical and cultural management strategies to target weed seeds present at harvest. A three-year trial was initiated to determine if continual HWSC methods selects for earlier seed set and shattering in Louisiana soybean. No shifts in weed populations or shattering time were examined. However, there was a significant reduction in weed density and the weed seed present in the soil seedbank. Weed communities present in a soil seedbank are influenced by production practices and environmental conditions. Therefore, utilizing multiple effective weed management strategies is imperative in reducing the soil seedbank.

Integration of Chaff Lining into Weed Management Programs in Soybean. Katie M. Mestayer*[1], Gabrielle LaBiche[1], Karla L. Gage[2], Steven Mirsky[3], Claudio G. Rubione[4], Lovreet S. Shergill[5], Mark VanGessel[4], Lauren M. Lazaro[1]; [1]Louisiana State University AgCenter, Baton Rouge, LA, [2]Southern Illinois University Carbondale, Carbondale, IL, [3]USDA-ARS, Beltsville, MD, [4]University of Delaware, Georgetown, DE, [5]USDA-ARS & University of Delaware, Beltsville, MD (246)

Weeds are constantly evolving and adapting resistance to herbicides. Nonchemical weed controls are becoming increasingly critical to continue to control weeds. Harvest weed seed control is a nonchemical weed management tactic that targets potential herbicide resistant weeds from entering back into the soil seedbank. One of these tactics is chaff lining, which funnels the chaff and weed seed into a windrow to break down or decay over winter. Simulated chaff lines with weed seed additions were distributed in a weed-free soybean field in four states. The integrated weed management system consisted of the presence/absence of a cereal rye cover crop and simulated chaff lines in the fall and an herbicide program (PRE or PRE + POST) that is typical to soybean growers. Weed counts were taken in quadrants at 0, 7, 14, 21, and 28 days after the PRE and POST applications, and again before harvest. Weed counts were taken inside and outside of the simulated chaff lines. All treatments had greater efficacy when combined with a cover crop. Chaff alone did not always provide suppression of germination, but there may be an interactive effect of chaff lining impacts and herbicide program. Over a long-term management scenario, seeds would be concentrated in specific locations in the field for improved control through the practice of chaff lining. These practices add an additional measure to the non-chemical methods which farmers can integrate with chemical and other control practices to reduce the soil seedbank.

Soil Surface Effects on Finger and Flextine Cultivation Efficacy in Vegetables. Daniel M. Priddy*[1], Daniel C. Brainard[1], Zachary D. Hayden[2], Monique Hemker[1]; [1]Michigan State University, East Lansing, MI, [2]Michigan State Univeristy, East Lansing, MI (247)

Seed bed preparation and soil management history are thought to have a large impact on the efficacy of mechanical cultivation, but limited information is available on of the mechanisms of these effects, and their implications for management. In a series of field trials, we tested how pre-plant bed preparation (rolled vs not), historic compost use (12 previous years of annual applications vs none), and presence of soil crust (induced through application of molasses) influenced soil surface characteristics and the efficacy of flextine cultivation in bush beans (*Phaseolus vulgaris*) and sweet corn (*Zea mays* L.). Rolling beds prior to planting generally resulted in lower soil surface roughness, greater soil micro-penetrometer resistance, higher soil moisture content, and reduced efficacy of flextine cultivation compared to unrolled beds. Historic compost and molasses applications had few impacts on these soil characteristics and little or no effect on flextine efficacy. The results of this study challenge conventional cultivation wisdom that rolling seed beds improves cultivation efficacy by facilitating more uniform tine working depth. This potential benefit may be offset by higher soil moisture and surface hardness, which reduce the capacity of tines to disturb soil and increase the re-rooting potential of disturbed weeds.

Electrical Discharge Systems for Weed Control in Agronomic and Horticultural Crops.
Lynn M. Sosnoskie*[1], Bryan Brown[2], Elizabeth Maloney[1], Julie Kikkert[3]; [1]Cornell University, Geneva, NY, [2]New York State Integrated Pest Management Program, Geneva, NY, [3]Cornell Cooperative Extension, Canandaigua, NY (248)

Weeds are a significant concern in annual cropping systems. While herbicides are commonly used to manage unwanted vegetation, chemical control tools are not always effective (e.g. evolution of herbicide resistance) or available (e.g. crop sensitivity). Consequently, growers are investigating other options, such as electrical weed control, to prevent crop yield losses. Electrical weeders work by generating a high voltage current, which is applied directly to the target via foliage contact and conducted downward through the roots. As the current passes through the plant, electrical resistance generates heat; this results in the vaporization of cellular water, leading to cell membrane rupture and plant death. Electric weed control technology is not new; the first electric weeders were patented in the 1880's. In the 1970's and 1980's, electrical weeding was studied in sugar beets for the control of weeds and bolting crop plants. Currently, there is renewed interest in electrical weed control (EWC) in both agronomic and horticultural crops. In 2020, observational studies were undertaken, with the assistance of grower-cooperators, in organic soybean fields located in western (Akron) and central (Cato) New York to describe the performance of electrical weeding under commercial conditions. Early season weed control at each field site was achieved using cultivation; EWC was initiated when weeds exceeded the height of the crop canopy. All field sites were managed by farms that owned and operated Weed Zapper units. The Weed Zapper, which is driven by a tractor PTO, is a generator that produces 100,000+ watts of electricity; the resulting current is distributed along a front-mounted applicator bar positioned above the crop canopy. Weeds that contact the bar are electrocuted. A fixed transect was established in the center of each field and 30 evenly spaced quadrats (each 2 m by 2 m in size) were located along its length from field end to field end. The identity, density, height, and vigor of the weeds occurring in each quadrat were evaluated before and after use of the Weed Zapper to describe changes in weed cover and vigor in response to EWC. Crop height and injury were also assessed. Aboveground tissue samples were collected from treated and untreated plants of the dominant weed species to assess EWC effects on biomass accumulation. Each of the surveyed fields were significantly infested (many quadrats > 50% cover) with multiple weed species, the most common being: lambsquarters (*Chenopodium album*), pigweed species (*Amaranthus* spp.), common ragweed (*Ambrosia artemisiifolia*), velvetleaf (*Abutilon theophrasti*), foxtail species (*Setaria* spp.), and barnyardgrass (*Echinochloa crus-galli*). Weed injury symptoms following EWC were characterized by wilting of treated tissue (within one hour of contact with the bar), followed by tissue necrosis that could either be localized or extend throughout the plant. Individual injury estimates varied (5% to 85%) with respect to both species' identity and plant size (which likely influenced contact time with the electrified bar). Fresh weights of foxtail spp., smooth pigweed, velvetleaf, and common ragweed were reduced 60% to 86% by EWC compared to non-treated plants. Crop injury did not exceed 15% in any quadrat. While collective weed vigor decreased over time in response to EWC use, overall density was not always similarly affected due to regrowth of treated plants and the appearance of later-emerging weeds. 2021 trials will focus on manipulative studies conducted in soybean, edamame, snap beans and beets to describe the biological (e.g. weed identity, density, size, and rooting structure), environmental (e.g. soil moisture content), and application (e.g. tractor speed) factors that influence the success of EWC.

Control of Annual Ryegrass (*Lolium rigidum*) and Turnipweed (*Rapistrum rugosum*) with a Diode Laser. Guy Coleman*[1], Michael J. Walsh[2]; [1]University of Sydney, Camden, Australia, [2]University of Sydney, Narrabri, Australia (249)

The development of accurate and precise weed recognition technology is creating an opportunity to implement non-chemical, non-selective weed control approaches. Methods such as lasers and electrical weeding could provide an alternative to herbicide use in face of growing resistance levels globally. Lasers are a highly targeted delivery method for thermal energy, reducing off-target damage and the potential for wasted energy. Preliminary research using a 25 W 975 nm fibre-coupled diode laser with a 5 mm spot diameter has highlighted the opportunity of lasers to provide control of annual ryegrass (*Lolium rigidum*) and turnipweed (*Rapistrum rugosum*) up to the three-leaf stage, however, there was no control of the mid to later tillering weeds tested. This study refined the energy density levels tested across four growth stages recording plant dry weight and survival at three-weeks post treatment. Four growth stages (G1 - youngest, G2, G3, G4 - oldest) for each species were tested, between 0.1 and 6.7 g, and 0.2 and 8.0 g for annual ryegrass and turnipweed respectively. The highest energy dose was increased from 76.4 J mm^{-2} to 304.8 J mm^{-2} for the largest two growth stages. Using a dose response model, annual ryegrass had a significantly ($P < 0.05$) lower ED_{90} than turnipweed for G1, G2 and G3 plants. A 90% reduction in biomass was not observed for the G4 plants, though growth depression was indicated at the ED_{50} level. With limited control of the largest weeds at the highest treatment level, further research should investigate opportunities for improved energy delivery efficiency with measures such as dynamic laser beam positioning and focusing.

Herbicide Efficacy in Agronomic Crops A

Acuron XR Herbicide - Residual Weed Control, Crop Safety and Yield in Corn. Scott E. Cully*[1], Mark J. Kitt[2], Tom H. Beckett[3]; [1]Syngenta Crop Protection, Marion, IL, [2]Syngenta Crop Protection, Greensboro, NC, [3]Syngenta, Greensboro, NC (250)

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.

Do Tank Mix Partners with Isoxaflutole Increase Soil Residual Activity Across the Cotton Belt? Delaney C. Foster*[1], Peter A. Dotray[2], Todd A. Baughman[3], Seth A. Byrd[4], A Stanley Culpepper[5], Darrin M. Dodds[6], Steven D. Hall[7], Jacob P. McNeal[6], Bradley J. Norris[6], Reagan L. Noland[8], Scott A. Nolte[9], Mason T. House[10], Jason K. Norsworthy[11], Rodger B. Farr[11], Larry Steckel[12], Corey Thompson[13]; [1]Texas Tech University, Lubbock, TX, [2]Texas Tech University and Texas A&M AgriLife Research and Extension Service, Lubbock, TX, [3]Oklahoma State University, Ardmore, OK, [4]Oklahoma State University, Stillwater, OK, [5]University of Georgia, Tifton, GA, [6]Mississippi State University, Mississippi State, MS, [7]Mississippi State University, Starkville, MS, [8]Texas A&M AgriLife Extension, San Angelo, TX, [9]Texas A&M AgriLife Extension, College Station, TX, [10]Texas A&M University, College Station, TX, [11]University of Arkansas, Fayetteville, AR, [12]University of Tennessee, Jackson, TN, [13]BASF, Abernathy, TX (251)

The increase in number of herbicide resistant weeds threatens cotton (Gossypium hirsutum) production and profitability and forcing producers to use multiple herbicide modes of action to effectively manage weeds. P-hydroxyphenylpyruvate dioxygenase (HPPD) inhibitors are a relatively new class of herbicide chemistry first available for use in the 1980's. While current varieties do not tolerate HPPD inhibitors, BASF Corporation has developed HPPD-tolerant cotton that will allow growers to use isoxaflutole in future weed management programs. Using multiple modes of action that include soil residual herbicides will increase weed management options and help in the stewardship of old and new technologies to slow the selection and spread of herbicide resistant weeds. In 2019 and 2020, a multi-state research project was developed to examine weed control following isoxaflutole applied preemergence alone and when used with a number of different individual tank mix partners at their full and reduced label rates. There were nine or ten locations conducted in six states in both years. In 5 of 7 locations, Palmer amaranth (Amaranthus palmeri S. Watson) was completely controlled at 14 days after application when isoxaflutole was mixed with the full rate of fluometuron, prometryn, and S-metolachlor. At 28 days after application, Palmer amaranth was controlled =95% at 6 of 7 locations with the addition of the full rate of diuron and fluridone. The addition of the full rate of diuron and fluridone provided the greatest control 42 days after application at 4 of 7 locations. These results indicate that isoxaflutole applied preemergence alone or in tank mixture is efficacious on Palmer amaranth and extended control may be achieved when isoxaflutole is tank mixed with a number of currently available soil residual cotton herbicides. Tank mix partners will be especially important in environments where isoxaflutole does not provided extended soil residual activity.

Acuron GT Launch: T-minus Spring 2021. Ryan D. Lins*[1], Tom H. Beckett[2], Mark J. Kitt[3]; [1]Syngenta Crop Protection, Rochester, MN, [2]Syngenta, Greensboro, NC, [3]Syngenta Crop Protection, Greensboro, NC (252)

Influence of Various Broadleaf Herbicides on the Control of Corn and Other Grasses with Clethodim Herbicides. Gregory K. Dahl[1], Joshua J. Skelton*[2], Laura J. Hennemann[3], Ryan J. Edwards[3], Amanda Flipp[3]; [1]Winfield United, Eagan, MN, [2]WinField United, Saint Paul, MN, [3]Winfield United, River Falls, WI (253)

Studies were conducted in 2020 at River Falls, Wisconsin to document the influence of broadleaf herbicides on the performance of clethodim for control of corn. 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 2021 Weed Science Society of America Meeting. Section® Three (clethodim) herbicide was applied at 59 g ai/ha and 118 g ai/ha alone or with a High Surfactant Oil Concentrate (HSOC) adjuvant at 0.6 L/ha. The clethodim alone and clethodim plus HSOC treatments were applied alone or in a tank-mixture with dicamba (1.6 L/ha), 2,4-D choline (2.33 L/ha), or bentazon (2.33 L/ha). All treatments were applied at a spray volume of 140 L/ha at 414 kPa to 36-cm tall corn plants with a backpack sprayer. The dicamba containing treatments were applied with TTI 11002 nozzles, and the remaining treatments were applied with AIXR 11002 nozzles. Clethodim plus HSOC applied at 59 g ai/ha and 118 g ai/ha provided 95% and 97% corn control 23 days after treatment, while clethodim alone at 59 g ai/ha and 118 g ai/ha provided only 23% and 50% control. Clethodim (59 g ai/ha) plus HSOC tank-mixed with dicamba, 2,4-D choline, or bentazon provided 55, 45, and 29% corn control 23 days after treatment. Corn control with clethodim (59 g ai/ha) plus HSOC was much less when tank-mixed with the broadleaf herbicides compared to clethodim plus HSOC alone. Clethodim (118 g ai/ha) plus HSOC tank-mixed with dicamba, 2,4-D choline, or bentazon provided 93, 97, and 85% corn control 23 days after treatment. Corn control with clethodim (118 g ai/ha) plus HSOC applied alone was equal to when tank-mixed with any of the broadleaf herbicides. The rate of clethodim applied in a tank-mixture with dicamba, 2,4-D choline, or bentazon should be raised compared to clethodim applied alone to overcome the potential herbicide antagonism and reduction in corn control.

Do New Herbicide Technologies for Grain Sorghum Differ in Effectiveness on Arkansas Johnsongrass Accessions? Jacob A. Fleming*, Jason K. Norsworthy; University of Arkansas, Fayetteville, AR (254)

Due to genetic similarities between johnsongrass and grain sorghum, few herbicides are available that will remove the troublesome weed effectively without injuring the crop. To combat this issue multiple new herbicide resistance technologies are being developed in grain sorghum to help producers, with some of these set for commercialization in 2021. These technologies include resistance to both acetyl CoA carboxylase (ACCase) and acetolactate synthase (ALS) inhibitors. To determine the effectiveness of the herbicides that will be labeled in these new technologies, accessions of johnsongrass from Arkansas were collected and a greenhouse study conducted in Fayetteville, AR in 2020. Johnsongrass seeds were collected from a total of 63 fields within 6 counties in eastern Arkansas. These accessions were threshed and then seeded in the greenhouse, where seedlings were treated with imazamox at 53 g ai ha^{-1}, fluazifop at 210 g ai ha^{-1}, quizalofop at 46 g ai ha^{-1}, and nicosulfuron at 47 g ai ha^{-1}. All herbicides were applied with 1% v/v crop oil concentrate. The goal was to determine which new herbicide technology would be most effective at controlling johnsongrass across a wide assortment of accessions to help producers make an informed decision when choosing a technology. Overall, the two ACCase inhibitors, quizalofop and fluazifop, showed the highest levels of control with a percent mortality of greater than 90 percent across all accessions tested. The lowest percent mortality was for nicosulfuron, which only killed 31% of the plants treated. Imazamox resulted in a percent mortality of 53 percent. These findings show that ALS inhibitors will be ineffective at controlling Arkansas johnsongrass accessions in many fields. If Arkansas grain sorghum producers are planting into areas with known johnsongrass pressure, the best option is to utilize the ACCase inhibitor technology.

Evaluation of Herbicide-Resistant Grain Sorghum Technologies for Grass Weed Control in High Plains. Vipan Kumar*[1], Isaac N. Effertz[2], Taylor Lambert[1], Rui Liu[1], Brent Bean[3]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Manhattan, KS, [3]Sorghum Checkoff Program, Lubbock, TX (255)

Grass weed species pose a serious management challenge for sorghum producers in High Plains region. Lack of over-the-top herbicide (POST) options further exacerbate the problem of in-season grass weed control in sorghum. Recent development of three herbicide-resistant grain sorghum technologies viz. Inzen™, Igrowth™, and Double Team™ will allow producers to use POST applications of nicosulfuron, imazamox, and quizalofop-p-ethyl, respectively, for grass weed control. The main objectives of this research were (1) to determine the effectiveness of imazamox applied PRE on grass weed control in comparison to commonly used group 15 herbicides, and (2) to compare the efficacy of nicosulfuron, imazamox, and quizalofop-p-ethyl applied early- or late-POST at two different rates. Field experiments were conducted in fallow ground (corn stubble) in 2020 growing season at Kansas State University Agricultural Research Center in Hays, KS. Experimental site had a natural infestation of green foxtail. PRE herbicide programs, including imazamox (53 and 78 g ha^{-1}), s-metolachlor (1604 g ha^{-1}), acetochlor (1680 g ha^{-1}), and dimethenamid-P (945 g ha^{-1}) were tested; whereas, imazamox (53 and 78 g ha^{-1}), nicosulfuron (36 and 54 g ha^{-1}), and quizalofop-p-ethyl (46 and 88 g ha^{-1}) were tested in early- or late-POST timings. All treatments were arranged in a randomized complete block design with 4 replications. PRE treatments were applied on April 16, 2020, whereas EPOST and LPOST treatments were applied on June 4, 2020 (8 to 10-cm tall green foxtail) and June 24, 2020 (30 cm tall green foxtail), respectively. Data on percent visible control of green foxtail were recorded at biweekly interval throughout the growing season and aboveground shoot biomass was determined at the end-of the season. Among PRE programs, imazamox tested at both rates provided an excellent control (89 to 94%) of green foxtail up to 50 days after PRE (DAPRE), whereas control did not exceed more than 51% with any group 15 herbicides. Among EPOST programs, quizalofop-p-ethyl at 88 g ha^{-1} was the best performing treatment with 95% green foxtail control at 28 days after EPOST (DAEPOST). Green foxtail control with EPOST treatments of imazamox, nicosulfuron, and quizalofop-p-ethyl (46 g ha^{-1}) was moderate and ranged from 77 to 83% at 28 DAEPOST. Green foxtail control with LPOST treatments of imazamox, nicosulfuron, and quizalofop-p-ethyl was inadequate and ranged between 14 and 31% at 21 days after LPOST (DALPOST). Furthermore, the shoot biomass reduction of green foxtail was consistent with percent control ratings with highest reduction (78%) observed with EPOST treatment of quizalofop-p-ethyl applied at 88 g ha^{-1}. In conclusion, these results indicate that PRE applied imazamox (53 and 78 g ha^{-1}) can provide excellent residual activity on green foxtail control in Igrowth™ sorghum, whereas quizalofop-p-ethyl at 88 g ha^{-1} applied in early-season can provide effective control of green foxtail in Double Team™ sorghum.

“Herbicide Efficacy in Agronomic Crops B”

Impact CORE: A New Herbicide Premixture for Postemergence Use in Corn. Richard M. Porter[1], Joseph A. Bruce*[2]; [1]AMVAC Chemical Corporation, Ankeny, IA, [2]AMVAC Chemical Corporation, Glen Carbon, IL (256)

Impact CORE® is an emulsifiable concentrate formulation containing 857 g ai L^{-1} of acetochlor and topramezone at a 100:1 ratio, respectively, without safener. US EPA has approved Impact CORE applications in corn (field, silage, seed and pop) from spike to 28 cm height for postemergence and residual control of select grass and broadleaf weeds. Use rate is soil texture and organic matter dependent ranging from 1.25-2.5 kg ai ha^{-1}. Optimum application parameters include weeds up to 7.5 cm height, 140 L ha^{-1} water volume minimum, and nozzles producing 250-400 µm VMD droplets. When applied alone, preferred adjuvants include methylated seed oil at 0.5% v/v and ammonium sulfate at 2.8 kg ha^{-1}. Tank mixtures with atrazine or glyphosate may be used to broaden weed control spectrum. Preferred adjuvants for tank mixtures include nonionic surfactant at 0.25% v/v and ammonium sulfate at 2.8 kg ha^{-1}. Use of oil-based adjuvants in tank-mixtures is permitted but under some conditions, however, may result in temporary foliar necrosis, especially combinations with atrazine. Rain-free period for optimum activity is 1 hour. Most crops can be planted the year following application. Planting canola, dry edible bean, flax, green bean, pea or sugar beet requires an 18-month interval after application. Impact CORE is a trademark owned by AMVAC Chemical Corporation.

Do Planting Date and Environmental Conditions Impact Rice Tolerance to Florpyrauxifen-benzyl? James W. Beesinger*, Jason K. Norsworthy, Leonard B. Piveta, Mason C. Castner; University of Arkansas, Fayetteville, AR (257)

Injury caused to rice by florpyrauxifen-benzyl has been observed across cultivars, environmental conditions, and management practices. Producers, threatened with herbicide-resistant weeds, should be able to use every site of action available to them to control weedy species in their fields without concern of yield loss, delayed development, or loss of groundcover caused by herbicide injury. Identifying the factors effecting rice injury caused by florpyrauxifen-benzyl could allow for better recommendations, minimizing injury while maximizing efficacy. A field experiment was conducted in 2019 and 2020 near Stuttgart, Arkansas to determine the impact of application date on the severity of injury caused by florpyrauxifen-benzyl. Three separate planting dates were used to ensure that applications did not occur in similar environmental conditions. Applications of 15, 30, and 60 g ae ha^{-1} of florpyrauxifen-benzyl were applied at the preflood (4-5 leaf) rice stage. Injury ratings and grain yield from the trial led to the conclusion that certain environmental conditions must exacerbate rice injury caused by florpyrauxifen-benzyl. Two experiments were conducted at the Altheimer Lab in Fayetteville, Arkansas to determine the effect of environmental conditions on rice injury caused by florpyrauxifen-benzyl. In the first experiment, rice cultivar XP753 was planted in 7.5L buckets filled with a silt loam soil and placed in a greenhouse. The buckets were maintained at moisture levels of 40, 60, 80, and 100% field capacity. Another experiment was initiated in a similar way. Soil containing buckets were maintained at a moisture level of 100% field capacity and placed in a growth chamber. The growth chamber was programmed for a day/night temperature of 35/24C while a divider allowed for one side of the growth chamber to receive a higher light intensity (1200 $\mu mol/m^2/s$) than the other side (700 $\mu mol/m^2/s$). Rice in both experiments was treated with florpyrauxifen-benzyl at 30 g ae ha^{-1} at the three-leaf growth stage, and rice plants in the buckets were flooded to a depth of 5 cm five days after application. Rice in soil maintained at 100% field capacity displayed more injury and had a greater reduction in biomass than any other soil moisture treatment (35%), leading to the conclusion that a higher level of soil moisture presets a greater risk for injury caused by florpyrauxifen-benzyl. Applications made in low light conditions yielded more injury than those made under high light intensity. Data from these studies will help explain when the risk for rice injury from florpyrauxifen-benzyl is greatest and will aid development of strategies to minimize a deleterious effect on the crop.

Impregnating Florpyrauxifen-benzyl on Urea for Weed Control in Rice. Bodie Cotter*, Jason K. Norsworthy, James W. Beesinger, Tristen H. Avent, Leonard B. Piveta; University of Arkansas, Fayetteville, AR (258)

Off-target movement of aerially-applied florpyrauxifen-benzyl to soybean (*Glycine max*) became a major concern following commercial launch of the herbicide in 2018 in rice (*Oryza sativa*). A small-plot field trial was initiated in the spring of 2020 at the Milo J. Shult Agricultural Research and Extension Center in Fayetteville, AR that evaluated control of key rice weeds, specifically barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], yellow nutsedge [*Cyperus esculentus* (L.)], and hemp sesbania [*Sesbania herbacea* (Mill.) McVaugh], using florpyrauxifen-benzyl impregnated on urea fertilizer in an attempt to reduce off-target movement of a foliar spray. Herbicide applications of florpyrauxifen-benzyl and florpyrauxifen-benzyl + penoxsulam, both foliar spray and impregnated, were made at two flood depths (5 and 15 cm) to the weed species and results analyzed as a single-factor completely randomized design. At 28 days after treatment (DAT), yellow nutsedge and hemp sesbania were effectively controlled by all herbicide treatments and application methods with visual control being greater than 97% for either weed species. Conversely, at 28 DAT, barnyardgrass was not effectively controlled by florpyrauxifen-benzyl alone impregnated on urea at both flood depths. Florpyrauxifen-benzyl impregnated on urea only controlled barnyardgrass 46% and 23% at a 5 and 15 cm flood, respectively. Likewise, florpyrauxifen-benzyl impregnated on urea produced a mortality rate of 38% and 25% at a 5 and 15 cm flood depth, respectively. Overall, florpyrauxifen-benzyl alone effectively controlled yellow nutsedge and hemp sesbania applied using either application methods, however, the addition of penoxsulam, as a premix, added additional support to control barnyardgrass by foliar spray and impregnation.

The Effects of Rate and Timing of Pre-harvest Glyphosate on Malting Barley (*Hordeum vulgare*). Breanne D. Tidemann*[1], John T. O'Donovan[1], Hiroshi Kubota[1], K. Neil Harker[1], T. Kelly Turkington[1], William May[2], Eric N. Johnson[3], Brian Beres[4], Marta Izydorczyk[5], Lori Oatway[6], Patricia Juskiw[6], Henry de Gooijer[2], Alick Mulenga[7]; [1]Agriculture and Agri-Food Canada, Lacombe, AB, Canada, [2]Agriculture and Agri-Food Canada, Indian Head, SK, Canada, [3]University of Saskatchewan, Saskatoon, SK, Canada, [4]Agriculture and Agri-Food Canada, Lethbridge, AB, Canada, [5]Canadian Grain Commission, Winnipeg, MB, Canada, [6]Alberta Agriculture and Forestry, Lacombe, AB, Canada, [7]Agriculture and Agri-Food Canada, Scott, SK, Canada (259)

From 2013-2016, effects of pre-harvest glyphosate application on malting barley were evaluated at five locations: Lacombe, Beaverlodge and Lethbridge, AB and Indian Head and Scott, SK, Canada. Two rates of glyphosate were tested (900 and 1125 g ai ha^{-1}), at three different timings (soft dough, hard dough and maturity). Each of these glyphosate applications were made on AC Metcalfe and CDC Meredith malting barley varieties, and an untreated check was included for each variety. Mixed model analysis was conducted in SAS 9.4 with distribution and heterogeneous variance selected according to Bayesian Information Criterion. Yield was significantly affected by variety, and glyphosate timing nested in glyphosate rate. Yield was most commonly reduced with earlier glyphosate applications, particularly at the soft dough stage. However, there were also measured reductions in yield when glyphosate was applied at the hard dough stage compared to the maturity stage. Maturity applications showed no significant difference in yield when compared to the untreated checks. Variety was the only component that had a significant effect on kernel weight, test weight, and kernel protein. Percent plump kernels was affected by variety and glyphosate rate while lodging was not affected by any treatment factors. Overall, based on this study, even on-label glyphosate applications can reduce yield. Impact of these applications on quality parameters and residue levels will be important for further recommendations on use of pre-harvest glyphosate in malting barley.
Breanne.tidemann@canada.ca

Topramezone + Glufosinate: A Unique Premixture. Richard K. Zollinger*[1], Peter Porpiglia[2]; [1]AMVAC Chemical Corporation, Spokane Valley, WA, [2]AMVAC Chemical Corporation, Newport Beach, CA (260)

Sinate® herbicide is a soluble liquid premix containing topramazone acid at 11 g/L and glufosinate-ammonium at 296 g/L. This mixture is approved for use by the U.S. Environmental Protection Agency on glufosinate tolerant field corn (grain and silage) and sweet corn. Labeled rates are 482 to 642 g/ha. The higher rate is the broadcast season maximum cumulative amount per treated acre per year. Application to field corn is from emergence up to 61 cm tall/V7 stage of growth and up to 91 cm tall with drop nozzles between corn rows. Broadcast application in sweet corn is from emergence to V6 stage of growth. Methylated seed oil concentrate (preferred), high surfactant methylated oil concentrate, petroleum-based oil concentrate, or nonionic surfactant adjuvants with ammonium sulfate are required. Sinate controls more than 110 small grass and broadleaf weeds. Atrazine may be added at 286 to 1714 g/ha for improved weed control. Corn response was <1.5% in developmental field research. Most crops can be planted the year following application at the lower rate but canola, some dry edible bean types, flax, green beans, pea, and sugarbeet require an 18-month interval after application before planting. The rain-free period for optimum activity is 4 hours. Visual evaluations showed no antagonism from the contact action of glufosinate on systemic topramezone. A possible theory to explain this phenomenon is the delayed 4 to 12-hour absorption of glufosinate allowing for rapid absorption and translocation of topramezone. Glufosinate is highly hydrophilic which may decrease rate of absorption. Topramezone is highly lipophilic which may increase rate of absorption. Expression of phytotoxicity from glufosinate is 2 to 4 days rather than 2 to 4 hours from herbicides that form peroxides in plants. The delayed plant tissue desiccation from glufosinate may allow time for the rapid absorption and translocation of topramezone. Topramezone may contribute to increased efficacy of glufosinate in non-optimal environmental conditions. However, application to weeds 8 cm in height or less provides consistent efficacy. Application with residual Group 15 herbicides extends grass and small-seeded broadleaf weed control to 42 days after application.

Diuron Use in Oklahoma Wheat Double-crop Soybean Systems. Misha R. Manuchehri*[1], Todd A. Baughman[2], Robbie W. Peterson[2], Zachary R. Treadway[2], Hannah C. Lindell[1], Lane S. Newlin[1], Caitlyn C. Carnahan[1], Justin T. Childers[3]; [1]Oklahoma State University, Stillwater, OK, [2]Oklahoma State University, Ardmore, OK, [3]Oklahoma State University, Marlow, OK (261)

Diuron is often applied in late winter or early spring in Oklahoma winter wheat to control wild buckwheat (*Fallopia convolvulus*) and other troublesome broadleaf weeds. Once wheat is harvested from these fields, many growers will immediately plant soybeans in double-crop systems. Per the diuron label, treated acres should not be replanted to any other crop within one year after the last treatment. To evaluate soybean response to diuron treated wheat acres, a study was established at Bixby (very fine sandy loam soil) and Kildare (silt loam soil) Oklahoma in 2017-2018 and again at Kildare in 2019-2020. Diuron was applied at 900, 1350, 1800, 2700, 3600, and 4040, and 5400 g a.i. ha^{-1} to winter wheat in late winter/early spring, harvested in mid-June, and then immediately planted to soybean. Winter wheat yields were not reduced when following recommended label rates except for at Kildare in 2018 when wheat following the lowest rate was 269 kg ha^{-1} less than the nontreated control. All diuron treatments resulted in little to no visual soybean injury and no yield differences relative to the nontreated control. Additionally, diuron provided 20 to 96% and 60 to 99% control of Palmer amaranth (*Amaranthus palmeri*) in 2018 at Bixby and Kildare, respectively. Diuron is an effective herbicide for wild buckwheat control in winter wheat and could be a tool for Palmer control in wheat double-crop soybeans if soil type, application date, and soybean planting date is carefully considered.

“Phytochemical Impacts on Weeds”

Characterization of Sicklepod Extract as a Deer Repellent and Insecticide for Soybean Looper (Lepidoptera: Noctuidae). Ziming Yue*[1], Charles L. Cantrell[2], Natraj Krishnan[1], David J. Lang[1], Mark W. Shankle[3], Te-Ming (Paul) Tseng[1]; [1]Mississippi State University, Mississippi State, MS, [2]USDA ARS Natural Products Utilization Research Unit, Oxford, MS, [3]Mississippi State University, Verona, MS (263)

Sweet potato (*Ipomoea batatas* (L.) Lam.) is the seventh most important food crop in the world. It can produce more edible energy per hectare per day than other C3 crops such as wheat, rice, and cassava. Mississippi annually grows 28,000 to 30,000 acres of sweet potatoes and ranks No. 3 after North Carolina and California by USDA. Weed competition and interference can reduce sweet potato yield by 40-90%. In Mississippi, the yield reduction due to weeds can reach up to 81%. Early-season competition and interference from weeds, especially the first six weeks after transplanting, are extremely critical. The standard weed management methods include manual weeding, mechanical and chemical methods. The limitations of the first two methods make the chemical methods necessary. However, the chemical methods are limited by few options of herbicide. Clomazone alone is not effective on Palmer amaranth, flumioxazin controls Palmer but not nutsedge, and S-metolachlor is effective on Palmer and nutsedge but also reduces yield and quality. Most herbicides are limited to wick on row-middles but not spray within rows. Previous research focused on herbicide selection, application rate, timing, and application methods; herbicide tolerance has not been evaluated in sweet potato. This project evaluated tolerance of selected sweet potato cultivars to dicamba and 2,4-D with the long-term goal of developing a practical weed control program for sweet potato in Mississippi. The experiments included two steps: first, 0.1-1X dicamba and 0.1-1X 2,4-D were used to screen the survivors among 20 sweet potato cultivars; second, 0.4X dicamba and 0.2X 2,4-D were used (based on step 1 results) to evaluate the response contrast between the tolerant cultivars and Palmer amaranth seedings. The results showed the tolerant sweet potato cultivars and Palmer amaranth had contrast response to both dicamba and 2,4-D, suggesting dicamba and 2,4-D can be used for in-row application on sweet potato. By combining herbicides with other modes of action, a practical weed control program can be achieved for these sweet potato cultivars.

Suppression of Germination and Growth by Industrial Hemp (*Cannabis sativa* L.) Extracts and Residue. Avery Shikanai*; Southern Illinois University Carbondale, Carbondale, IL (264)

Industrial hemp (*Cannabis sativa* L.) accumulates terpenoid and cannabinoid secondary metabolites in glandular trichomes. However, any adaptive function of the secondary metabolites in hemp is not well understood. Previous work has demonstrated the phytotoxicity of individual cannabinoids and terpenes, but it is not known whether the complex mixture of these chemicals found in hemp residue can affect other plants. 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 5 mg mL^{-1}. 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. Seedlings were counted and removed as they germinated over 30 days under greenhouse conditions. Results of a one-way ANOVA suggest that in laboratory conditions, 5 mg mL^{-1} hemp extract significantly reduced germination of kale [$F_{7,151}$= 11.23, P <0.001]. The average number of kale seeds that germinated per experimental unit decreased from 7.6 in the control to 1.5 in the 5 mg mL^{-1} treatment. In the greenhouse study, addition of 5 g hemp residue to the soil surface significantly delayed and reduced the germination of waterhemp in comparison to the no residue control (Bonferroni adjusted P<0.0001) and the corn residue control (Bonferoni adjusted P= 0.00012) [overall log-rank test $?^2(2)$=97.8, P<0.0001].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.

The Effect of Variability in Climatic Conditions on the Control Efficacy of Tumble Pigweed (*Amaranthus albus*) in Processing Tomatoes. Roni Gafni*[1], Lior Blank[2], Hanan Eizenberg[3]; [1]Hebrew University of Jerusalem, Rehovot, Israel, [2]Agricultural Research Organization, Volcani Center, Rishon Lezion, Israel, [3]Newe Ya'ar Research Center, Ramat Yishay, Israel (265)

Tumble pigweed (*Amaranthus albus*) is a noxious weed competing with processing tomatoes worldwide. In Israel, four major tomato growing regions are located in the northern part of the country, in a geographical region characterized by a unique climatic gradient spreading over a relatively short distance. The varying climatic conditions (temperature, precipitations, etc.) affect various agricultural aspects, such as planting dates and pesticide and herbicide applications. Metribuzin and rimsulfuron are commonly used herbicides for the control of *A. albus* in processing tomatoes. However, in recent years, reduced herbicide efficacy was observed across all growing regions. Our aim is to understand the contribution of the regional environmental conditions to the herbicide efficacy of *A. albus* in processing tomatoes. Seeds of *A. albus* were collected from all four growing regions. Plants from eight populations were grown under similar conditions and progeny seeds were collected. Plants of maternal and progeny populations were phenologically characterized under natural summer conditions at the Newe Ya'ar Research Center. Time required for the emergence of true leaves (TL) ranged between 1 to 1.5 days and there were no significant differences between generations across populations. Metribuzin and rimsulfuron response was tested for four representing populations. Herbicides were applied at the recommended field rate for three phenological stages: 4-6, 6-8 and 8-10 TL. For all populations, sufficient weed control was recorded when metribuzin was applied prior to six TL stage. However, at and above four TL stage, rimsulfuron was not effective, except for the Hulata population. Herbicides were tested under two temperature regimes: 16°C/22°C night/day (simulating early plantings at eastern regions) and 28°C/34°C night/day (late plantings, western regions). Rimsulfuron was highly efficient under a cold temperature regime only, while metribuzin successfully controlled plants of all populations regardless of the temperature regime. Our work shows that the window of opportunity for effective control of *A. albus* is narrow and varies among growing regions, as growth rates are different under various climatic conditions. Thus, our results indicate the need to move to a regional based, site-specific *A. albus* management.

Assessing Impacts of Drought on Weed Communities in the Great Lakes Region. Allyson M. Rumler, Erin E. Burns*; Michigan State University, East Lansing, MI (266)

Nearly all crop production is impacted by drought. Significant corn yield losses can occur during years when in-season rainfall is limited during pollination and grain fill. Future climate scenarios for the Great Lakes Region predict more precipitation in heavy rainfall events, leaving more days during the growing season that have little or no precipitation, polarizing the wet and dry periods. To address this future climate scenario a field study was conducted in East Lansing, MI in 2018-2020 evaluating the impacts of reduced precipitation and weed competition on drought and non-drought tolerant corn hybrid performance. The study was conducted as a split-plot randomized block design with four replications. Whole plots were assigned to a corn hybrid with and without the Genuity® DroughtGard® trait. Sub-plots were factorial combinations of one of three weed densities (weed-free, 50% weeds, 100% weeds) and presence or absence of precipitation. Rainout shelters were designed to impose 70% rainfall interception. Weed density by species was measured three times during the season. Weed biomass by species was collected at the end of the season. Dominant weed species in 2018 included: common lambsquarters (*Chenopodium album*), Powell amaranth (*Amaranthus powellii*), velvetleaf (*Abutilon theophrasti*), and green foxtail (*Setaria viridis*). Dominant weed species in 2019-2020 included: green foxtail (*Setaria viridis*), common lambsquarters (*Chenopodium album*), horseweed (*Conyza canadensis*), and common purslane (*Portulaca oleracea*). In 2018, weed density was not impacted by precipitation level or corn hybrid. In 2019-2020, weed density was not impacted by corn hybrid. However, weed density was lower under reduced precipitation than under ambient precipitation (p=0.003). Furthermore, in 2018-2020 weed communities under reduced precipitation were more diverse than weed communities under ambient precipitation (p=0.099). Additionally, species evenness was found to be more uniform under reduced precipitation (p=0.001). Overall, results highlight water stress modifies weed community composition and density in a rainfed corn system.

Influence of Cover Crops on Soil Microbial Activity and Degradation of Atrazine and *S*-Metolachlor. William G. Johnson[1], Bryan G. Young[2], Shalamar Armstrong[1], Eileen J. Kladivko[1], Joshua R. Widhalm[1], Manoj S. Ghaste[1], Lucas Oliveira Ribeiro Maia*[1]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, Brookston, IN (267)

The use of cover crops as one management tool within the integrated weed management approach has gained popularity among US growers. However, the influence of this practice on soil residual herbicide degradation is still not clear and requires further investigation. Therefore, field trials were conducted at two locations between Fall 2019 and Summer 2020 to evaluate the effect of cereal rye (*Secale cereale* L.) and crimson clover (*Trifolium incarnatum* L.) cover crops on soil microbial activity and degradation of atrazine and *S*-metolachlor. Treatments included both cover crop species and a fallow control. The soil residual herbicides tested were divided into no residual, medium and heavy residual (load based on the number of herbicides applied). Cover crops were planted in the early Fall of 2019 and terminated three weeks before Corn (*Zea mays* L.) planting in the late Spring of 2020. Soil samples were collected the day before termination and 3, 4, 8, 12, and 16 weeks after termination (WAT) to determine the activity of ß-glucosidase (BG) and dehydrogenase (DHA). Samples from 3 to 16 WAT were also used to determine atrazine and *S*-metolachlor concentrations. None of the herbicides affected the BG activity, which was influenced by cover crop biomass, soil temperature and organic matter content. Greater cover crop biomass and soil organic matter content from site 1 resulted in 2-fold more BG activity in this site relative to site 2. Atrazine concentration at site 1 was reduced by an average of 82% across cover crop treatments between 3 and 4 WAT. Within the same period, *S*-metolachlor concentrations at site 1 and site 2 were reduced by 60 and 70%, respectively, across cover crops. No clear effect of atrazine and *S*-metolachlor were observed on DHA activity. This study shows that the use of cover crops occasionally results in increased BG and DHA activity, which may lead to enhanced degradation of soil residual herbicides. However, more data is required to support the hypothesis of this research.

"Dynamics of Weed Seed Germination and Emergence"

Impact of Bio-solarization on Soil Conditions and Weed Seedbank in Tomato Field. O. Adewale Osipitan*[1], Jesus D. Fernarndez-Bayo[1], Brad Hanson[2], Mohsen B. Mesgaran[1]; [1]University of California - Davis, Davis, CA, [2]University of California - Davis, Winters, CA (268)

Bio-solarization has been successfully accomplished in a variety of soil organic amendments, usually as byproducts from food processing system for pest control. This study was conducted to evaluate the potential of crop biomass generated on field during a quarantine crop destruction scenario, to create a lethal environment for weed seeds in the soil. Specifically, a field study was conducted to determine the differential impact of soil organic amendments using industrial tomato processing pomace, as well as plant debris from tomato at an early development stage (young plant debris without fruits) and at a late development stage (mature tomato plant debris with unripened fruits). This effect was tested with or without solarization to assess the importance of elevating soil temperature using tarps to kill weed seeds [common lambsquarters (*Chenopodium album*), field bindweed (*Convolvulus arvensis*), and redroot pigweed (*Amaranthus retroflexus)*]. Treatments combination included incorporated mature tomato plant debris covered with tarp (OBS) or without tarp (ONT), incorporated tomato pomace at 0.68% w/w amendment rate covered with tarp (TPBS) or without tarp (TPNT); incorporated young tomato plant debris covered with tarp (YBS) or without tarp (YNT); non-amended soil covered with tarp (CBS) or without tarp (CNT, as control). Our study indicated that soil organic amendment using tomato plant debris caused seed mortality of common lambsquarters, field bindweed and redroot pigweed. On overall weed mortality, there was no difference in the level of mortality caused by young or matured tomato plant debris, however, the later caused greater mortality compared to the use of tomato pomace. When covered with a tarp, the organic amendments generally provided improved weed seed mortality, suggesting the importance of combining organic amendment and solarization (a combination called bio-solarization), as a technique for weed control. The greatest weed seed mortality was provided by bio-solarization that utilized the matured tomato plant as organic amendment (OBS); which caused up to 47% seed mortality of redroot pigweed. The OBS provided 30 and 19% seed mortality of common lambsquarters and field bindweed respectively, however, these were not different from mortality provided by TPBS and YBS. Seed mortality caused by bio-solarization can be attributed to the increase in soil temperature, moisture, and a volatile fatty acid. By implication, this study suggested that bio-solarization can be used to deplete weed seedbank using tomato-based organic amendment, thereby reducing weed pressure in the following crops in a tomato field.

Cranberry Seed Germination as Affected by Environmental Conditions. Thierry E. Besancon*; Rutgers University, Chatsworth, NJ (269)

Cranberry (*Vaccinium macrocarpon* Aiton) is a native species of the New Jersey Pine barrens, where cross-pollination occurs frequently between wild plants and selected cultivars planted for commercial production. Seeds from cross-pollination are viable and produce off-type varieties with lower fruit production and stronger vegetative vigor. Off-type varieties can easily out-compete planted cultivars, lowering the yield potential of cranberry bogs over time. Because of limited existing literature data, laboratory and greenhouse studies were conducted to determine the effect of temperature regimes, pH, water stress, lighting conditions, and sowing depth on cranberry germination. Onset was faster in an alternating 20 / 30 C temperature regime, whereas total germination (98%) tended to be greater at 10/20 C and 15 / 25 C. As expected for an acidophilic species, germination onset was faster at pH 3-5 than higher pH; however total germination did not decrease as pH increased. Emerged seedlings showed reduced root and shoot development as pH increased, while production of leaves and secondary roots 30 d after seeding was stopped for pH greater than 4. Cranberry germination was not affected by the absence of light nor by red light compared to natural light condition but decreased by 5% on average when exposed to far-red light. No germination occurred below -0.8 mPa while rate and total germination significantly decreased at solution osmotic pressure lower than 0.4 mPa. Germination onset decreased with increasing burial depth, while total germination decreased by 48% when depth increased from 1 to 2 cm and no germination occurred at 4 cm. These data suggest that emergence of off-type cranberry seedlings may occur over a long period ranging from mid-spring to late summer in New Jersey. Seed sensitivity to burying could be exploited by growers through the deposition of sand over the top of crop canopy which is an operation frequently conducted for stimulating the rooting of new cranberry stolons.

Thermal Time to Emergence of California Weedy Rice (*Oryza sativa* f. *spontanea*) Under Flooded Field Conditions: A 2-year Study. Liberty B. Galvin*[1], Whitney Brim-DeForest[2], Kassim Al-Khatib[1]; [1]University of California - Davis, Davis, CA, [2]University of California Division of Agriculture and Natural Resources, Yuba City, CA (270)

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

Emergence Pattern of Economically Important Weeds in the North-Central, Mid-Atlantic, and South-Central Regions of the United States. Lovreet S. Shergill*[1], Adam Davis[2], Jason A. Bond[3], Jason K. Norsworthy[4], John Lindquist[5], Kevin W. Bradley[6], Lauren M. Lazaro[7], Mandy Bish[6], Mark VanGessel[8], Michael L. Flessner[9], Muthukumar V. Bagavathiannan[10], Nicholas Jordan[11], Steven Mirsky[12]; [1]Montana State University, Huntley, MT, [2]University of Illinois, Urbana, IL, [3]Mississippi State University, Stoneville, MS, [4]University of Arkansas, Fayetteville, AR, [5]University of Nebraska - Lincoln, Lincoln, NE, [6]University of Missouri, Columbia, MO, [7]Louisiana State University AgCenter, Baton Rouge, LA, [8]University of Delaware, Georgetown, DE, [9]Virginia Tech, Blacksburg, VA, [10]Texas A&M University, College Station, TX, [11]University of Minnesota, St. Paul, MN, [12]USDA-ARS, Beltsville, MD (271)

Light and Red/Far-Red Ratio Responses of Bohemian Knotweed (*Reynoutria* × *bohemica*) Seed Germination and Seedling Growth. Virginia Oeggerli*[1], David R. Clements[1], Vanessa L. Jones[1], Delia D. Anderson[1], Jichul Bae[2]; [1]Trinity Western University, Langley, BC, Canada, [2]Agriculture and Agri-Food Canada, Agassiz, BC, Canada (272)

Knowing germination and growth requirements is essential when determining management strategies for invasive plants. Bohemian knotweed is a highly invasive plant throughout North America and is of particular concern in the Pacific Northwest. This species is a hybrid of Japanese knotweed (*Reynoutria japonica*) and Giant knotweed (*Reynoutria sachalanensis*). The resultant hybrid reproduces via both rhizomes and seeds, having retained both means of reproduction from its parent species, although the relative contribution that seeds play in dispersal is unknown. Clonal knotweed patches produce dense shade, potentially impacting seed germination and seedling growth. We conducted trials on the impact of light quantity and quality on seed germination and seedling growth in Bohemian knotweed. We demonstrated that Bohemian knotweed seeds do not have a light requirement, based on >10% germination in full darkness in all four temperature settings. The ideal germination settings for Bohemian knotweed were 14 hours light, 10 hours dark at 24h 20°C, resulting in 96% germination. However, there was significant variability in germination rates among populations. Red to far-red light ratios (R:FR) of 0.3, 0.6, and 1.0 were utilized to investigate germination and seedling growth, representing a range from deep shade (R:FR of 0.3) to full sunlight (R:FR of 1.0). The R:FR ratio 0.3 had lower germination rates (50%) than both higher ratios (both were 61%) ($p = 0.01$). Leaf number was significantly less in the 0.3 R:FR ratio than the 1.0 ratio ($p = 0.0447$). Seedling height was not reduced by lower ratios of R:FR. Shade responses of Bohemian knotweed seedlings were measured under four light intensities: full light, 400 lux, 200 lux and complete darkness. Seedlings within the shaded condition (200 or 400 lux) exhibited the greatest vertical growth ($P < 0.05$). Leaf number was less in the shaded trials than the full light trial ($P < 0.05$). Seedlings grown under shaded conditions showed limited leaf surface area growth. Overall, the presence of a canopy may not reduce the number of successful germinants but significantly impacts the architecture of Bohemian knotweed seedlings, likely resulting in mortality under prolonged shade which could explain the lack of seedlings found in proximity to established Bohemian knotweed stands. Furthermore, different populations varied greatly in germination rates making it difficult to make a generalization about the light requirements of the species. Future studies could investigate reasons for these differences, such as genetic makeup, physical location of the site, and previous chemical treatments.

Weed Community Response to Four Years of Repeated Application of Calcium or Magnesium Sulfate to Soil. Andrea Leiva Soto*[1], Catherine P. Herms[1], Allison M. Robinson[1], Steve Culman[1], Douglas Doohan[2]; [1]The Ohio State University, Wooster, OH, [2]The Ohio State University, Wooser, OH (273)

Soil balancing (SB), the practice of amending soils to achieve Ca:Mg ratios of approximately 6:1, has been used for decades by some Midwestern farmers and consultants to interpret soil mineral tests and guide soil management practices. Among the benefits claimed by SB practitioners is a decrease in weed problems. More than half of Ohio and Indiana organic grain farmers interviewed (n=29) associated the occurrence of weeds with one or more nutrients or minerals present or lacking in the soil. Despite skepticism by the scientific community and the considerable expense of amendments to achieve the desired ratio, many farmers continue to follow a SB approach. We evaluated weed community response to Ca:Mg ratios from 2015 to 2018 by amending plots with gypsum (calcium sulfate) and Epsom salt (magnesium sulfate) in a RCBD with crop rotation as the main effect and soil amendments as the subplot factor. Two test sites with clay- and silt-loam soils with CEC of 22 and 10 ($cmol_c$ kg^{-1}), respectively, were used. Plots were planted to a rotation of corn, soybean and cereal grains, and amended annually with gypsum or Epsom to create divergent soil Ca:Mg ratios. Soils were sampled each spring and fall to assess the weed seedbank and Ca:Mg ratio, respectively. Field weed emergence was followed annually at the silt loam site. Weeds were more responsive at the silt loam site compared to the clay loam site. Averaged across crops, broadleaf seedbank densities were 23 and 35% larger after two and three years of Epsom application, respectively, and grass seedbank densities were 66% larger after two Epsom applications. Grass seeds were more abundant in Epsom-treated plots in the soybean rotation in 2016 and the corn rotation in 2017. Field weed emergence in the silt loam soil showed the same trend effect as the seedbank results. Emerged broadleaf weed density across crops was 42% larger and grass density 21% larger, after three and two years of Epsom application, respectively. By crop, a similar increase due to Epsom was seen for emerged broadleaves and grasses in small grains (2017) and corn (2018), respectively. At the clay loam site, seedbank densities differed only one year. In Epsom-treated plots, density of grass seeds in 2017 was about 30% larger across all crops, and was 86% higher in the small grain rotation. This study is the first to provide evidence that Ca:Mg ratios in soil can impact weed community dynamics in organic agricultural systems.

“New Insights into Weed Competition”

The Critical Period for Photosynthesis and the Legacy of Competition. Andrew McKenzie-Gopsill*[1], Sasan Amirsadeghi[2], Sherry Fillmore[3], Clarence Swanton[2]; [1]Agriculture and Agri-Food Canada, Charlottetown, PE, Canada, [2]University of Guelph, Guelph, ON, Canada, [3]Agriculture and Agri-Food Canada, Kentville, NS, Canada (281)

Photosynthetic responses of common bean (*Phaselous vulgaris* L.) to increasing durations of weed-free and weedy environments were investigated using a critical period for weed control study under field conditions. The presence of weeds induced the shade avoidance response and was accompanied by a reduced red to far-red ratio (R/Fr) of reflected light supporting previous assertions it is an important signal regulating crop-weed interactions. Despite increases in stomatal conductance and leaf intercellular [CO_2] with increasing duration of weed presence, CO_2 assimilation and photosynthetic efficiency continually declined. This coincided with reduced Calvin cycle capacity suggesting induction of biochemical rather than stomatal limitations on photosynthesis. Weed removal prior to reproductive stages resulted in maintenance of high photosynthetic capacity. When weed presence extended to reproductive stages and beyond the critical period for weed control, however, CO_2 assimilation and photosynthetic efficiency never recovered. Yield was highly correlated with photosynthetic efficiency and in a similar manner, declined with increasing durations of weed presence through reduced seeds per plant. We conclude that the lasting consequence of weed competition is impairment of photosynthesis, which may provide an important mechanism to explain yield loss.

The Importance of Singlet Oxygen in Resource-independent Competition. Nicole Berardi*, Clarence Swanton; University of Guelph, Guelph, ON, Canada (282)

Neighboring weeds can influence the proportion of far-red (FR) light a plant is exposed to by reflecting unused FR light horizontally, altering the light quality a plant receives. The altered light environment is detected through a decrease in the ratio of red to FR light. This form of plant interaction is considered resource-independent competition and can have detrimental effects on plant growth. Recently, FR light has been shown to enhance the production of singlet oxygen in plants. Under normal physiological conditions, singlet oxygen acts as an important signalling compound that is involved in regulating the expression of specific sets of genes and essential physiological processes. However, when singlet oxygen is produced in excess it can cause irreversible damage to proteins, lipids and DNA resulting in photoinhibition of photosynthesis and cell death. To further explore the mechanisms surrounding resource-independent plant competition and the involvement of singlet oxygen, *Arabidopsis thaliana* was studied under a FR-enriched environment. Results indicate that singlet oxygen is a major reactive oxygen species involved in resource-independent competition. Our results also establish a link between singlet oxygen and the TOR kinase signalling pathway, a major regulator of plant growth and development. Further identification of these responses would provide important insights into the molecular basis of plant competition and the central role that singlet oxygen plays under these conditions.

Using Plant Growth Regulators to Enhance Carrot Competitiveness with Weeds. Jordan Schuler*, Jed Colquhoun, Richard Rittmeyer, Daniel J. Heider; University of Wisconsin - Madison, Madison, WI (283)

The use of plant growth hormones, such as gibberellic acid and abscisic acid, has been an increased point of interest for growers with the goals of enhanced crop seed germination rate and early-season crop competitiveness, as well as inhibited weed seed germination. Preliminary research on this topic has been reported, but a majority of that work ceased with the increased availability of effective synthetic herbicides. In 2019, a Petri dish study was conducted and repeated with eight common vegetable crop seeds, each with four replicates, under six treatments of gibberellic acid ranging from non-treated to 640 ppm. Each dish included a piece of filter paper and 10 ml of distilled water, with another 10 ml of distilled water added after two days. Seed germination was counted every two to four days, with germinated seeds extracted from the Petri dishes. The results from these Petri dish studies were variable with the strongest enhancement in seed germination from gibberellic acid noted in cabbage. In subsequent similar research, the interaction of temperature and gibberellic acid response was explored with carrot seed, noting a stronger germination enhancement at cooler than warmer temperatures. The role of plant hormones (gibberellic acid, abscisic acid, cytokinin and indole butyric acid, applied alone and in combination) was also investigated in controlled environment pot studies that included Palmer amaranth (Amaranthus palmeri S. Watson), redroot pigweed (Amaranthus retroflexus L.) and velvetleaf (Abutilon theophrasti Medik.). Palmer amaranth germination rate increased where the cytokinin was applied (regardless of rate) and where gibberellic acid was applied at a 320 ppm concentration. Redroot pigweed germination increased where abscisic acid was applied at the rate of 2.5 g per kg seed. Research in the upcoming growing season will focus on practical field applications of the knowledge gained in these controlled environment studies.

Faba Bean Crop Competition Effects on Common Sowthistle (*Sonchus oleraceus*) Growth and Reproductive Development. Asad Shabbir*[1], Adam McKiernan[2], Michael Widderick[2], Michael J. Walsh[3]; [1]The University of Sydney, Camden, Australia, [2]Department of Agriculture and Fisheries, Toowoomba, Australia, [3]University of Sydney, Narrabri, Australia (284)

Resistance to herbicides and the lack of new herbicide options have led researchers to explore alternate methods to manage weed populations in large-scale cropping systems. Crop competition is an effective weed management approach that can reduce the pressure on herbicides, particularly in less competitive crops such as faba bean (*Vicia faba* L). This research aimed to measure the impact of faba bean cultivar (Nasma, Warda, Marne), row spacing (25 and 50cm), and crop density (20 and 30 plants m^{-2}) on biomass and seed production of common sowthistle (*Sonchus oleraceus* L) in field trials at two locations (Narrabri, NSW, and Toowoomba, QLD) in the northern grains region of Australia. When faba bean row spacing was reduced from 50 to 25 cm, weed biomass and seed production were reduced by 64% and 33%, respectively. Similarly, when faba bean density was increased from 20 to 30 plants m^{-2}, the biomass of sowthistle was reduced by 31%. The cultivar Nasma planted at 30 plant m^{-2} suppressed the sowthistle seed production 36% more compared to Marne. At Narrabri, faba bean yield was not affected by crop density or row spacing. At Toowoomba, increasing faba bean plant density from 20 to 30 plants m^{-2} increased grain yield by 13%. Weed management through crop competition is an effective and affordable control strategy that farmers should consider.

Linkages Among Weed Control, Weather Variability, and Soybean 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 (285)

Anthropogenic climate change continues to present challenges to soybean production. Since the 1950's in the Midwest, carbon emissions have increased, temperatures have risen, and rainfall has become more variable. These climate trends are predicted to continue throughout the 21st century. Both variable weather and weed interference influence crop performance; however, their combined effects on soybean yield is poorly understood. The objective of this research was to determine the most important relationships among weed control, weather variability, and crop management on soybean yield loss due to weeds. A database of 106 individual herbicide evaluation trials spanning 26 years was used to model the relationship between weed control and soybean yield loss due to weeds. The database was analyzed using regression, random forests (RF), and classification and regression tree (CART) analyses. When weeds were not controlled, an average yield loss of 49% was observed; however, yield loss attenuated as percent weed control increased. RF and CART confirmed late-season weed control was as a major driver of soybean yield loss, with yield losses increasing as weed control deteriorated. Additionally, a linkage between inadequate weed control and warmer, drier conditions was identified. Low rainfall and higher average air temperatures during soybean seed filling exacerbated yield losses due to poorly controlled weeds. Since the Midwest is heading towards drier, warmer conditions, the risk of soybean yield loss will increase without significant improvements in weed management systems.

Multiple Years of Competition Between *Ailanthus altissima* (Tree of Heaven) and *Rhus typhina* (Staghorn Sumac: Removal Success and Impacts of an Herbivore. Cynthia Huebner*; USDA Forest Service - Northern Research Station, Morgantown, WV (286)

The spread of invasive plants may be facilitated by their greater competitive ability compared to associated native plants or, instead, by their opportunistic establishment of disturbed sites with open niches. Early successional sites may be more susceptible to opportunistic invasion depending on the abundance and composition of native species present natural or via restoration efforts. Defining the competitive interactions between typical early-successional native plants and potential invaders is key to predicting invasion or restoration success, especially after a disturbance. Our goal was to evaluate the competitive ability of *Ailanthus altissima* (Miller) Swingle (AA; invasive exotic tree) and *Rhus typhina* L. (RT; native early-*successional* tree), supplementing data from previous research showing no difference when the species are at equal densities, but superior competitive ability of RT when the latter is in densities 5RT to 1AA. This research evaluates densities of 2, 3 and 4 RT to 1 AA after three years of growth, the impacts of species interactions on RT's sexual reproduction, potential impacts of a natural herbivore (*Atteva aurea* (Fitch); Ailanthus webworm) on young AA seedlings, and the effect of herbicide application to both species on adjacent stems. Trees were grown from seed in a common garden with six replicates of each density type. Both survival and basal diameter measures were compared within and across density combinations using general linear mixed models. Effects of density on RT reproduction and herbicide effects (all-but-one stem of the same species removed, all AA stems removed, or no removal) were compared using a Fishers exact test. Our results showed that RT had larger individual stems on average starting at a density of 2RT to 1AA though the differences between species were not significant. However, combinations of 2-5 AA to 1RT showed the single RT stems had significantly greater basal diameters on average than the AA stems, suggesting AA suffered from greater intraspecific competition than interspecific competition and that RT is the better competitor. This study also showed that AA seedlings were susceptible to ailanthus web worm, with the greatest damage occurring when no large trees of either species were present. With large trees present, 36% of all planted seedlings had webworm. Seedlings under density combinations with RT were less likely to show herbivory by the webworm. Of all flowering RT trees, 69% were female and 46% of all trees flowered with no significant differences among the density combinations though the 1RT to 0AA and 3RT to 1AA shared in the largest number of flowers. Under an-all-but-one stem being treated by herbicide, both AA and RT were unlikely to experience death of the one remaining untreated stem, but there was evident herbicide damage to 40% of the RT remaining stems. Under herbicide treatment where all AA stems were treated, 3% of the remaining untreated RT stems died and 7% showed herbicide damage. RT stems (5.5%) that were not associated with any herbicide treatment also showed herbicide damage. These findings confirm that RT is more competitive than AA at densities as low as 2RT stems to 1AA and that associations with AA do not decrease RT's ability to flower. Ailanthus webworm may increase AA seedling mortality but herbivory is less likely to have an impact with adult trees of either species near the seedlings. Herbicide application of AA and RT may spread to other RT stems, causing some damage, though death is unlikely. These results have implications for integrated pest management involving herbicide, biocontrol, and competitive interactions with native plant species.

"Herbicide Efficacy in Broadleaf Crops"

A23372A - A Broad-Spectrum Solution for Superior Weed Management in Soybean. Brett R. Miller*[1], Peter Eure[2], Tom H. Beckett[3], Ryan Jackson[4]; [1]Syngenta Crop Protection, Fargo, ND, [2]Syngenta Crop Protection, Greensboro, NC, [3]Syngenta, Greensboro, NC, [4]Syngenta Crop Protection, Carrollton, MS (287)

A23372A: A Broad-Spectrum Solution for Superior Weed Management in Soybean.Brett R. Miller*[1], Tom H. Beckett[2], Ryan Jackson[3] and Pete Eure[2], [1]Syngenta Crop Protection, Fargo, ND, [2]Syngenta Crop Protection, Greensboro, NC, [3]Syngenta Crop Protection, Carrollton, MS. 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 *trifida*), morningglories (*Ipomoea*) 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.

Biologically Effective Dose of Bromoxynil, Applied Alone and Tankmixed with Metribuzin, for the Control of Glyphosate-Resistant Canada Fleabane (*Conyza canadensis)* Applied Preplant in Soybean. Peter Sikkema, David Hooker, David Westerveld*, Darren Robinson; University of Guelph, Ridgetown, ON, Canada (288)

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, interference 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 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 ha^{-1} controlled GR Canada fleabane 50 and 80%, respectively. When tankmixed with metribuzin, bromoxynil at 10, 25, and 54 g ha^{-1} controlled GR Canada fleabane 50, 80, and 95%, respectively. No soybean injury was observed. At 8 WAA, bromoxynil + metribuzin (280 + 400 g 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.

Response of Putative Glyphosate-resistant Horseweed Accessions from Wisconsin to Spring Burndown Herbicides. Alexandre T. Rosa*, Nicholas J. Arneson, Nikola Arsenijevic, Rodrigo Werle; University of Wisconsin - Madison, Madison, WI (289)

Horseweed (*Erigeron canadensis*) is becoming a troublesome weed species in no-till corn-soybean cropping systems in Wisconsin. The objective of this study was to investigate the efficacy of commonly applied burndown and POST-emergence herbicides for horseweed control. The study was established at the University of Wisconsin-Madison Walnut Street Greenhouse during fall 2020 in a completely randomized design with six replications, and two experimental runs. Twenty-one populations from across Wisconsin and Northern Illinois were screened with nine herbicides. Herbicides were sprayed at their respective label rate (1x) except for glyphosate which was also sprayed at the 3x label rate. Glyphosate (1x and 3x), imazethapyr, mesotrione, atrazine, glufosinate, saflufenacil, and paraquat were sprayed using a stationary spray chamber calibrated to deliver 140 L ha^{-1} of spray solution using either AI9502EVS or DG9502EVS flat-fan nozzles. Dicamba and 2,4-D were sprayed off-site with a CO_2-pressurized backpack sprayer delivering 140 L ha^{-1} of spray solution using TTI110015 flat-fan nozzles. The herbicides were sprayed when horseweed reached approximately 9 cm in diameter. Visual herbicide efficacy (%) and biomass were collected at 21 days after treatment (DAT) Glufosinate, saflufenacil, and paraquat had the fastest activity and greatest effectiveness among all herbicides, with 100% control of all populations tested. Glyphosate and imazethapyr were the least effective herbicides. Glyphosate at 1x controlled 5% of the populations, whereas at 3x controlled 38%. Imazethapyr did not control any of the horseweed populations tested. From the 21 populations across WI and IL, 65% were not controlled by either glyphosate (1x and 3x) or imazethapyr. These findings are of importance to WI no-till producers searching for effective chemical options for spring herbicide burndown and in season POST-emergence control of horseweed. Future research includes dose-response analysis and molecular investigations of selected horseweed genotypes to glyphosate, imazethapyr, and 2,4-D.

Pollen-Mediated Gene Flow from Dicamba/Glyphosate-Resistant- to Conventional Soybean [*Glycine max* (L.) Merrill]. Zahoor A. Ganie*[1], Parminder Chahal[2], Amit J. Jhala[2]; [1]FMC, Newark, DE, [2]University of Nebraska - Lincoln, Lincoln, NE (290)

Second-generation genetically modified (GM) multiple herbicide-resistant (glyphosate + dicamba, glyphosate + 2,4-D + glufosinate, glyphosate + 2,4-D + glufosinate, glyphosate + glufosinate + isoxaflutole) soybean varieties are important for the weed control including glyphosate-resistant species. 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 into 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. To evaluate the risk of pollen-mediated gene flow from GM glyphosate + dicamba-resistant soybean into conventional non-GM soybean a field study was 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 GM glyphosate + dicamba-resistant soybean (AG32X8 brand variety, 3.2 maturity) and surrounded by receptor block planted with conventional non-GM soybean (ASGROW A3253 brand variety, 3.2 maturity) in rows spaced 30 cm apart. At the end of the growing season seeds were harvested from the receptor block at 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 pollen mediated gene flow over distance from the pollen-source during both the years. The highest frequency of gene flow was 0.009 and 0.006 in 2017 and 2018, respectively, detected at distance <2 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 99 reduction in PMGF were 0.5 m in 2017 and 0.8 m in 2018. The results indicated that risk of PMGF from GM herbicide-resistant- to non-GM soybean is less than 0.01% and the isolation distance should be at least >1 m.

Are Dicamba and Glufosinate Still Viable Options for Palmer Amaranth in U.S. Soybean Production Systems? Jason K. Norsworthy*[1], Tom Barber[2], Grant L. Priess[1], Michael M. Houston[1], Leonard B. Piveta[1], Kevin W. Bradley[3], Karla L. Gage[4], Aaron Hager[5], Greg Kruger[6], Larry Steckel[7], Daniel B. Reynolds[8], Bryan G. Young[9]; [1]University of Arkansas, Fayetteville, AR, [2]University of Arkansas System Division of Agriculture, Lonoke, AR, [3]University of Missouri, Columbia, MO, [4]Southern Illinois University Carbondale, Carbondale, IL, [5]University of Illinois, Urbana, IL, [6]University of Nebraska - Lincoln, North Platte, NE, [7]University of Tennessee, Jackson, TN, [8]Mississippi State University, Mississippi State, MS, [9]Purdue University, Brookston, IN (291)

Palmer amaranth is the most troublesome weed of U.S. agriculture of many reasons; one being it rapidly evolves resistance to herbicides. As fewer herbicides are available for control of this weed, it is imperative to understand which ones remain effective. Dicamba and glufosinate are two commonly applied postemergence herbicides in cotton and soybean, with the continued effectiveness of both being vital to successful control of Palmer amaranth through use of multiple sites of action. For this reason, Palmer amaranth accessions were collected fall of 2018 and 2019 from production fields in areas where either dicamba or glufosinate had been relied upon for multiple years. More than 150 accessions were collected for screening from Arkansas, Illinois, Mississippi, Missouri, Nebraska, and Tennessee fields. Greenhouse grown 5- to 6-leaf Palmer amaranth plants from each accession were treated with glufosinate and dicamba at a 7.5- to 10-cm height. Both herbicides were applied at a 0.5 and 1X rate, which was 297 and 594 g ai/ha for glufosinate and 280 and 560 g ae/ha for dicamba. The screening was conducted in two runs of 50 plants per accession each winter in the greenhouse. However, some accessions failed to germinate and some had limited seed supply that prevented establishment of sufficient plants for evaluation of all herbicide treatments. A total of 122 and 124 accessions were sufficiently evaluated for response to dicamba at a 0.5 and 1X rate, respectively, based on the criteria of 100 treated plants. For 0.5 and 1X glufosinate, 138 and 139 accessions were tested, respectively. Palmer amaranth survival exceeded 20% for 48 of 122 accessions following dicamba at 280 g ae/ha (0.5X). Increasing the dicamba rate to 560 g/ha resulted in 7 of 124 accessions having more than 20% survival. For glufosinate, survival exceeded 20% for 15 of 138 accessions following treatment with the 0.5X rate. Following treatment with the 1X glufosinate rate, 5 of 139 accessions had more than 20% survival. Achievement of 100% mortality or no survival is needed to ensure the absence of seed production, especially in areas of a field or time of year that competition from a crop is minimal. However, complete control (no survival) was only accomplished for 23 of 124 and 101 of 139 accessions following treatment with the 1X rate of dicamba and glufosinate, respectively. These results indicate that there are many fields where Palmer amaranth survival would be likely following a single application of either herbicide, especially considering that well-watered, succulent plants grown under greenhouse conditions were treated at a spray volume of 187 L/ha. Conditions during treatment, timing, and spray coverage were likely far better than would be expected under field conditions. Accession 19-62, collected from a field in Arkansas in 2019, was further evaluated for sensitivity to dicamba and glufosinate because of the ineffectiveness of both herbicides in the screen. Accession 19-62 was compared to a susceptible standard over a range of dicamba and glufosinate doses with the results fit to a 3-P exponential model. Accession 19-62 was 2.9-fold less sensitive to dicamba

and 3.5-fold less sensitive to glufosinate than a susceptible standard based on LD50 values. A few plants survived treatment with a 2X rate of both herbicides. The field where this Palmer amaranth accession was collected had previously been in production of glufosinate-resistant cotton and soybean for approximately 10 years with multiple applications of the herbicide often applied each year. The findings from this screening indicate there are biologically significant differences in sensitivity of Palmer amaranth to glufosinate and dicamba among crop fields today, with some fields containing progeny capable of surviving labeled rates of dicamba and glufosinate, even when applied under ideal conditions.

Reduction of Palmer Amaranth (*Amaranthus palmeri*) Growth Surviving Glufosinate Treatments in Cotton (*Gossypium hirsutum*). Eric A. Jones*, Marco Antonio Fajardo Menjivar, Diego J. Contreras, Diego E. Salazar, Charlie W. Cahoon, Ramon G. Leon, Wesley Everman; North Carolina State University, Raleigh, NC (292)

Experiments were conducted at Clayton and Rocky Mount, North Carolina to quantify the vegetative growth and female biomass of Palmer amaranth (*Amaranthus palmeri*) surviving glufosinate treatments in soybeans (*Gossypium hirsutum*). Glufosinate (590 g ai ha^{-1}) was applied to 5-7 (EPOST), 7-10 (POST), and >10 cm (LPOST) Palmer amaranth. Clethodim and *S*-metolachlor were applied to control grass and later emerging weeds, respectively. Palmer amaranth (10 plants $plot^{-1}$) were allowed to grow with the soybeans for a growth comparison to the glufosinate-treated plants. Apical height and circumference were recorded weekly for six weeks. Female Palmer amaranth plants were harvested at the end of the season to determine the accumulated biomass. All main effects and interactions were significant for apical height, circumference, and female biomass ($P < 0.001$). Non-treated Palmer amaranth plants grew larger at Clayton compared to Rocky Mount; glufosinate-treated Palmer amaranth plants did not grow differently across treatments. Palmer amaranth only survived the EPOST glufosinate application at Clayton. Palmer amaranth plants exhibited apical and circumference growth during the six week evaluation period. Palmer amaranth treated at EPOST did not exhibit a change in circumference during the six week evaluation period. Despite the differential growth, female Palmer amaranth surviving glufosinate accumulated the same biomass. Results of the experiments provide evidence that Palmer amaranth surviving glufosinate treatments still exhibit growth, albeit significantly reduced compared to the in-crop Palmer amaranth plants.

“Challenges with Palmer amaranth Management”

Frequency of Herbicide Resistance in Palmer Amaranth (*Amaranthus palmeri*) Introduced into North Dakota Through Sunflower Screenings. Joseph T. Ikley*, Nathan H. Haugrud, Stephanie A. DeSimini; North Dakota State University, Fargo, ND (293)

Palmer amaranth (*Amaranthus palmeri*) was first discovered in North Dakota in 2018. The weed has since been discovered in 13 counties and has been added to the state's noxious weed list. Palmer amaranth was introduced in 2018 and 2019 through various means including cover crop seed and out-of-state harvesting equipment. A recent infestation was traced to a sunflower processing plant that sold screenings to farmers as animal feed. Samples found these screenings to contain numerous weeds including pigweeds, velvetleaf (*Abutilon theophrasti*), cocklebur (*Xanthium strumarium*), common lambsquarters (*Chenopodium album*), and grain sorghum (*Sorghum bicolor*). Pigweed seeds were the most common weed seed contaminant of the sunflower screenings, and subsequent sampling revealed 622 pigweed seeds per kg of screenings. Seeds were submitted to the National Agricultural Genotyping Center for genetic testing that revealed the seeds to be primarily Palmer amaranth. Three greenhouse experiments were conducted evaluate the presence and prevalence of herbicide resistance in the Palmer amaranth populations found in these screenings. An herbicide mode of action screen was conducted by applied 1x (in parentheses) and 3x ND field rates of glyphosate (1260 g ha^{-1}), imazamox (35 g ha^{-1}), fomesafen (198 g ha^{-1}), atrazine (560 g ha^{-1}), dicamba (560 g ha^{-1}), and 2,4-D (560 g ha^{-1}). Two additional resistance screens were conducted by spraying 112 plants with 1,260 or 35 g ha^{-1} of glyphosate or imazamox, respectively. Leaves from each plant that were tested for glyphosate resistance were genetically tested for markers corresponding to resistance. Results from the herbicide mode of action screen found the population to be resistant to field rates of glyphosate with 55% of tested plants surviving, imazamox with 77% survival, and atrazine with 64% survival. The results from the 112-rep resistance screens found 41% of plants survived glyphosate 21 DAT, 89% of which were genetically identified to have over-amplification of EPSPS as a resistance mechanism. The remaining 11% that survived had normal copy numbers of EPSPS, indicating another mechanism of glyphosate-resistance is present in the population. Of the plants screened for imazamox resistance, 81% of plants survived 21 DAT. Many individual survivors showed little symptomology, though some were severely stunted, but still alive 21 DAT. Due to the nature of being introduced through sunflower screenings from a sunflower processing plant, these new Palmer amaranth populations are likely a combination of numerous populations from the US, leading to the highly variable response to herbicides. Further research is needed to evaluate response to atrazine, dicamba, 2,4-D, and other herbicides that are typically used in North Dakota.

Improvements in Genetic Testing for the Identification of Palmer Amaranth in Seed Mixtures. Anthony Brusa*; University of Minnesota, Saint Paul, MN (294)

A. palmeri is an aggressive and prolific weed species that has major ecological and economic impacts on agricultural row cropping systems. Using morphological identification to distinguish *A. palmeri* from other *Amaranthus* species is difficult, which has led to the use of genetic testing becoming the standard for *Amaranthus* species identification. We have developed an improved genetic test to maximize the robustness and reliability of *A. palmeri* identification. We assembled a large and geographically diverse panel of *Amaranthus* accessions and utilized Genotyping by Sequencing (GBS) to identify novel species-specific single nucleotide polymorphisms (SNPs) from these populations. These diagnostic SNPs were then used to develop a genotyping assays through Kompetative Allele Specific PCR (KASP). Performance was assessed against a validation panel of 1,250 *Amaranthus* individuals of 9 species. The end result is a set of three KASP assays for identification of *A. palmeri*, for use either independently or in conjunction. Assays were tested against the most robust validation panel of *Amaranthus* individuals in publication thus far and demonstrated an accuracy of 99.7-99.9% on single sample validations. Additionally, these markers were tested for sensitivity by extracting *A. palmeri* seeds in combination with seeds from Tall Waterhemp (*A. tuberculatus*). All three markers are capable of reliably detecting a single *A. palmeri* seed in a pool of 200 *Amaranthus* sp. seeds ($p < 0.0001$). Our work represents an improvement over existing commercial assays in terms of sensitivity, robustness of validation, and ease of use.

The Potential of 1,4-naphthoquinone Natural Products as Bioherbicides for the Control of Herbicide-Resistant Amaranthus Species. Clarence Swanton*, Peter Smith; University of Guelph, Guelph, ON, Canada (295)

1,4-naphthoquinones are a diverse and biologically active group of natural compounds synthesized by plants. This group of natural products is involved in allelopathic and plant-microbe interactions. The most common compound in this class of chemistry is juglone. Research studies were initiated to test if juglone applied POST controlled herbicide-resistant Amaranthus spp. Research results confirmed excellent control of Amaranthus species resistant to a wide range of herbicides including groups, 2,4,5,7 and 9. The structural diversity of 1,4-naphthoquinones may provide opportunities for the development of new bioherbicides or be used as structural templates for the development of synthetic herbicides.

Metabolic Resistance to HPPD Inhibitors in Palmer Amaranth (*Amaranthus palmeri*) Does Not Facilitate Resistance Evolution to Glufosinate. Anita Küpper*[1], Erica Manesso[1], Roland S. Beffa[2], Todd A. Gaines[3]; [1]Bayer AG, Frankfurt / Main, Germany, [2]Bayer AG, CropScience Division, Frankfurt / Main, Germany, [3]Colorado State University, Fort Collins, CO (298)

The occurrence of metabolic resistance in Palmer amaranth (*Amaranthus palmeri*) populations has been steadily increasing over the years. It brought up the question whether populations with an increased capacity to metabolize herbicides already, are able to evolve resistance to herbicide from different sites of action faster than susceptible ones. In this study two populations from Kansas (KS-R) and Nebraska (NE-R) known to be resistant to the HPPD-inhibitor tembotrione via enhanced metabolism and two populations collected from the same States (KS-S, NE-S) that were tembotrione-susceptible went through four consecutive rounds of selection with glufosinate (0, 30, 59, 119, 178, 238, 297, 356, 475, 594 g a.i./ha). After each round the top 20 survivors of a population were grown to maturity and bulk-crossed to produce the next generation for selection. Parallelly, a separate batch of each of the populations was bulk crossed for four generations without any selection pressure. Greenhouse dose response tests with tembotrione (0, 7, 10, 20, 50, 92, 120, 250, 500 g a.i./ha) and glufosinate (0, 30, 59, 119, 178, 238, 297, 594, 1188 g a.i./ha) were then conducted with the first and last generations of each population to answer the following questions: 1) Would glufosinate resistance evolve in response to recurrent selection with low doses of glufosinate? 2) Are metabolic HPPD-inhibitor-resistant populations more likely to evolve glufosinate resistance? 3) Does HPPD-inhibitor resistance decrease in frequency over time in the absence of glufosinate selection? The results show that repeated selection with low dose rates of glufosinate over four generations in Palmer amaranth did not lead to glufosinate resistance. Furthermore, metabolic HPPD-inhibitor-resistant populations were no more likely to evolve glufosinate resistance than susceptible ones. A slight reduction in the frequency of HPPD-inhibitor resistance was observed after several generations without any selection, which could either be due to genetic drift and/or a fitness cost of HPPD-inhibitor resistance.

SYMPOSIUM - 1. SUSTAINABLE WEED MANAGEMENT – WHAT IS IT AND HOW ARE WE DOING?

Sustainability and Weed Control - is it a Compatible Tank Mix? Travis Legleiter*; University of Kentucky, Princeton, KY (176)

Sustainability is defined as the "ability to be maintained at a certain rate or level". By definition sustainability does not identify the object or subject to be maintained, although within the 21st century the term is largely associated with natural resources or ecosystems. In evaluating the sustainability of weed science or weed control it is pertinent to identify the objects or subject that are to be maintained. Focusing on the 21st century use of the word sustainability, many aspects of weed science, such as invasive weed control, no-tillage, vegetation management in waterways, and wildfire weed management all lend to maintaining natural resources. Specifically focusing on no-tillage as a practice promoted by weed scientist and soil scientist over the past forty years, it no doubt reduces soil erosion and loss as compared to tillage practices widely practice in the mid-20th century. It can also be argued that no-tillage preserves water resources, preserves energy through reduced fuel usage, and expands land usage potential. Although with the increase no-tillage acreage in the United States inevitably led to the selection of herbicide resistant weeds at a fairly rapid rate in the late 1980's and into the 1990's at a rate that was not sustainable for the agricultural chemical industry. This led to the herbicide resistant crop era with the introduction of the first HR crops in the mid 1990's. Herbicide resistant crops allow for the continued adoption of reduced tillage, reduced the number of herbicide applications, and again had the potential to save on fuel energy, all of which again can be argued as sustainable by the 21st century definition. Much like no-tillage though, the use of herbicides alone for weed control has resulted in rapid selection of herbicide resistant weeds over the past 20 years. Even with the recent addition of new herbicide resistant crops the ability to sustain chemical weed control with new introductions of HR crops is undeniably impossible as we have nearly exhausted all herbicide site of action options at this point in 2021. The future of weed control looks to depend on machine learning, robotics, sensing, and weed seed management all of which continue to uphold the sustainable attributes of no-tillage while reducing our reliance on chemical weed control which has shown to not be a long term sustainable weed control strategy.

Beyond Sustainable: A Food System to Restore the Planet. Michael Doane*; The Nature Conservancy, Kansas City, MO (177)

Global food system companies are making a fresh round of commitments to address environmental risks on climate change, water, biodiversity loss and land degradation. Most efforts to define and measure sustainability have traditionally focused on management practices or technologies to avoid, or lifecycle concepts of input-to-output ecological efficiency. Regenerative agriculture focuses on the opportunity to renew or rebuild ecosystem services which have been degraded through the production management process. Restoring the health and functionality of topsoil is central to concept. Management practices for healthy soils depend on diverse, integrated weed management practices to reduce the need for tillage while providing high productivity and profitable cropping systems. Innovative companies in the food system are now considering how they can advance regenerative agriculture in their supply chains and thereby reposition food production as part of the environmental restoration agenda.

What Sustainable Innovation Means to Me. Reza Rasoulpour*; Corteva Agriscience, Indianapolis, IN (178)

The world of product safety science reached a tipping point in 2007 with publication of the National Academy of Sciences report on “Toxicity Testing in the 21st Century: A Vision and a Strategy”. Outlined in this report was a framework to bring cutting edge innovations into safety assessments with the long-term goal of sustainable innovation. Since this time, there have been significant multi-sector efforts to develop models and platforms aligned to turning this vision into a reality. What once seemed like an apparent mirage grows closer to reality as the research community explores combination *in silico* and *in vitro* approaches to advance our toxicity testing methodologies. In this talk, we will go over basic principles of product safety assessment and share examples of how predictive platforms are being utilized to develop products of the future with more favorable environmental and human health profiles.

Perspectives on Sustainability from the WSSA-Herbicide Resistance Education Committee.
Jill Schroeder*; New Mexico State University, Las Cruces, NM (179)

The perspectives and approach of the WSSA-Herbicide Resistance Education Committee have undergone a major transformation since the committee was formed about 10 years ago. Initial work extended from development of educational materials and journal articles to convening national summits to discuss the problem and lay out the technical solutions available to address resistance. In 2018, a sub-committee made up of weed scientists, entomologists, economists, and social scientists attended a workshop designed to help organizations address 'wicked' problems. They realized that the approach of the committee to that point centered on discussions of “how do we fix the resistance problem”. The group came to recognize that our role should instead be to listen to all stakeholders and work to facilitate their actions to address resistance. Some of the activities undertaken by members of the committee to engage stakeholders will be addressed as well as how does this fit within the larger umbrella of sustainability.

Integrated Weed Management, from Buzzword to Reality. Catherine M. De Vulder*; Bayer AG, Monheim, Germany (180)

Bayer has advocated for many years to reduce overreliance on single weed control methods—such as usage of just a single mode of action in chemical weed control—and utilize a variety of weed management strategies instead. Our Integrated Weed Management programs provide tailored agronomic solutions designed to provide farmers with the economic and environmental long-term benefit of taking a holistic approach to weed management. This includes diversified tactics like utilizing multiple modes of action, crop rotation, cover crop planting and other cultural and mechanical practices. As part of our sustainability commitments, over the next ten years Bayer will invest around €5 billion into additional integrated weed management methods to manage weeds that can be the biggest impediment to raising a healthy crop. This investment is dedicated to new weed management solutions covering chemical and non-chemical tools, including digital advancements and agronomic support. This talk will share Bayer's operating framework as well as examples on how the promoted integrated weed management techniques can move us from buzzword to reality.

How Corteva is Shaping a Sustainable Future: Corteva Sustainability 2030 Goals. Todd Pilcher*; Corteva Agriscience, Indianapolis, IN (181)

"Sustainability" is the buzzword across all corporate America. It takes a different meaning in the agriculture world as we balance the image of bucolic agriculture with the reality of advanced technology. To address this, Corteva Agriscience has established Sustainability Goals to be achieved by 2030. Corteva Agriscience has a 100 year history of advancing the capabilities of the global farmer, and while the focus during this time has always been to advance agriculture, for the first time we have had a structured categorization addressing our products & service impact to farmers, the land, communities, and our internal operations. These goals are rooted in the core of our products, so it begins at R&D and continues down the line to a final marketable product, addressing the connection each product has to the achievement of these goals. Beyond internal achievements, the achievement of these goals will assist Corteva and agricultural partners align with other sustainability targets that are driving and influencing policy and consumer decisions.

5 Simple Ways to Communicate Our Role in Sustainability. Karen Meinders*; Corteva Agriscience, Indianapolis, IN (182)

More than ever before, today's consumers want to know where their food comes from and how it was produced. As agriculture professionals and subject matter experts, we have the opportunity to communicate how our industry and farmers across the world are using responsible and sustainable products and practices to produce a safe, abundant and nutritious food supply while protecting our natural resources. Understanding your audience, focusing on shared values, crafting an authentic message, using the right channel, and creating a two-way dialogue are five simple ways to share our role in advancing agricultural sustainability.

SYMPOSIUM - 2. A HISTORY, OVERVIEW, AND PLAN OF ACTION ON PPO INHIBITING HERBICIDES

Discovery and Mode of Action of Protoporphyrinogen Oxidase-Inhibiting Herbicides.

Stephen O. Duke*[1], Franck E. Dayan[2], Abigail Barker[2]; [1]University of Mississippi, Oxford, MS, [2]Colorado State University, Fort Collins, CO (223)

Early work with PPO herbicides showed that light was a requirement for activity, but the basis for this requirement was unknown until two labs in 1988 published studies showing that certain diphenyl ether herbicides cause the accumulation of protoporphyrin IX (proto). The following year, Matringe et al. and Witkowski and Halling demonstrated that this was caused by inhibition of protoporphyrinogen oxidase (PPO), even though proto is the product of the reaction catalyzed by this enzyme. They recognized that, as with the case of variegate porphyria, a human disease caused by a defect in PPO, inhibition of PPO caused the substrate to diffuse from the porphyrin pathway to other cellular compartments, where it is oxidized to proto by autoxidation and/or enzymatic oxidation by non-PPO oxidases. Outside the porphyrin pathways to heme and/or chlorophyll, proto accumulates and acts as a photodynamic compound, generating highly toxic reactive oxygen species (ROS) in the presence of molecular oxygen and light. There is a strong correlation between phytotoxicity and levels of proto. Fluorescence microscopy of PPO inhibitor-treated plant cells shows that proto accumulates on or in cellular membranes, where ROS can do great damage by generation of lipid peroxides from membrane lipids, resulting in rapid plasma membrane dysfunction. This is consistent with physiological studies of PPO inhibitor effects on plasma membrane function. Blocking the porphyrin pathway before PPO with inhibitors such as gabaculine prevents proto accumulation and herbicidal damage. The best PPO inhibitors are extremely efficient herbicides at low application rates because accumulation of proto can apparently occur by inhibition of only a small fraction the PPO in the cell. Unlike other toxic enzyme inhibitors, the cell is not starved for the enzyme product, but is poisoned by a small amount of a very toxic enzyme product that does not accumulate with properly functioning porphyrin synthesis.

History and Distribution of PPO-Resistant Weeds. Roland S. Beffa*; Bayer AG, CropScience Division, Frankfort / Main, Germany (224)

Since 2001, resistance to PPO inhibitors (group 14) was reported in *Amaranthus tuberculatus* in a soybean field. In addition, this population was found to be resistant to ALS-inhibitors (group 2) (Heap, 2021). Resistance was described for imazethapyr, thifensulfuron-methyl, chlorimuron-ethyl, fomesafen, lactofen, and acifluorfen-sodium. Since then, resistance to PPO inhibitors was reported for 14 weed species, in 8 crops, and in 7 countries distributed worldwide. *Amaranthus tuberculatus*, *Amaranthus palmeri*, and *Ambrosia artemisifolia* are the weed species with the most resistance cases reported; soybean and corn are the crops mainly concerned; and USA is the country showing the highest number of cases. In addition, on the 35 resistant cases described, 27 showed multi-resistance with herbicides active, in particular, on ALS (group 2), on EPSPs (group 9), or mimicking auxins (group 4). Several resistance mechanisms to PPO inhibitors were described including target site mutations and non-target site resistance, possibly detoxification of the active ingredient. These data will be discussed in the perspective of an Integrated Weed Management strategy. Heap, I. The International Herbicide-Resistant Weed Database. Online. Friday, January 10, 2021

Mechanisms of Resistance to PPO Inhibitors. Patrick Tranel*; University of Illinois, Urbana, IL (225)

Although herbicides that inhibit protoporphyrinogen oxidase (PPO) have been used since the 1960s, resistance to them was not first documented until 2001. The number of weed species resistant to PPO inhibitors has now grown to 13 (as reported by the International Herbicide-Resistant Weed Database), which is a modest number compared to other major herbicide groups. Although there are several potential mechanisms that could confer resistance to PPO inhibitors, an insensitive target site has been identified in 6 of the 13 resistant species. There are two target sites for PPO inhibitors: PPO1, which is localized to plastids and was largely thought to be the primary target; and PPO2, which generally was considered to be the mitochondrial isoform, but now known to be dually targeted to both mitochondrial and plastids in at least some plant species. With only one exception to date, target-site mutations conferring evolved resistance to PPO inhibitors have been associated with PPO2. The fact that PPO2 can be targeted to both organelles—and, therefore, a single mutation could result in a resistant enzyme in both locations—may explain the preponderance of mutations in the PPO2 gene. Known resistance-conferring amino acid changes in PPO2 that have evolved in weeds are: deletion of glycine at position 210, substitution of arginine 128 with leucine, glycine, methionine, or isoleucine, and substitution of glycine 399 with arginine. The glycine 210 deletion has been reported only in waterhemp (*Amaranthus tuberculatus*) and Palmer amaranth (*Amaranthus palmeri*). The codon deletion likely was fostered by the codon being within two, tri-nucleotide repeats in both species, a situation that does not occur at the homologous position in most other plant species. In general, the identified PPO2 amino acid changes confer cross resistance to many PPO inhibitors, although arginine 128 substitutions tend to confer lower levels of resistance and more narrow cross resistance compared to the glycine 210 deletion and the glycine 399 substitution. Palmer amaranth has shown the most diversity in PPO2 amino acid changes: not only has the glycine 210 deletion been identified in this species, but arginine 128 and glycine 399 substitutions have as well. In fact, various combinations of PPO2 changes often co-exist within resistant populations of this species, and double mutations also were identified recently within single alleles of the Palmer amaranth PPO2 gene. The one reported PPO1 change is substitution of alanine 212 with threonine, which confers narrow cross resistance, primarily causing resistance to oxadiazon. Besides target-site resistance, enhanced herbicide metabolism has been reported in some cases, but remains poorly understood. Interestingly, at least some cases of metabolism-based resistance to PPO inhibitors likely occurred as a result of selection by alternative herbicides. New PPO herbicides are being developed, so there remains much interest—and much more research to be done—in fully understanding resistance to this group of herbicides.

Greenhouse and Lab Methodologies for Detection of Resistance to PPO-Inhibiting Herbicides. R Joseph Wuerffel*; Syngenta, Gerald, MO (226)

Research on resistance to protoporphyrinogen oxidase inhibiting herbicides (PPO-R) is likely to intensify in the near future given pending commercialization of PPO-inhibiting compounds such as tiafenacil, trifludimoxazin and epyrifenacil and recently discovered novel target-site and non-target site resistance mechanisms in *Amaranthus* species and *Eleusine indica* [L.]. Here we will summarize past research and formulate best practices for confirming resistance to PPO-inhibiting herbicides. Several methods have been employed for detecting and confirming resistance to PPO-inhibiting herbicides. The two most frequently used approaches consist of whole plant dose-response assays and molecular SNP genotyping assays. In 2003, the first dose-responses on PPO-R in waterhemp (*Amaranthus tuberculatus* [Moq.] Sauer [syn. r*udis*]) were documented. Subsequently a molecular assay for the detection of the dG210 mutation endowing PPO-R in waterhemp was published in 2008. Since 2008 there have been over 20 publications on PPO-R in *Amaranthus* utilizing these fundamental research tools, providing a substantial amount of methodological information to guide future research. Dose-response regression estimates (e.g. GR_{50}/ED_{50}/LD_{50}) are fundamental for characterization and detection of herbicide resistance. Achieving multiple data points above and below 50% efficacy has been demonstrated to improve predictions of derived indices (R/S ratios); however, dose-response studies on PPO-R *Amaranthus* species often do not achieve this because PPO-inhibiting herbicides are highly potent when applied PRE or POST in the greenhouse. Published dose-response studies on PPO-R *Amaranthus* species have utilized a wide range of doses, crossing two to five orders of magnitude with varying degrees of success. The range of doses, the herbicide used, and stage of application impact the prospect of achieving a full dose response. For example, POST dose-response studies on PPO-R *Amaranthus* species utilizing fomesafen with doses ranging across three to five orders of magnitude typically achieved a complete dose response. Conversely, dose-response studies applying lactofen POST with a similar range of doses often did not achieve a full dose response with multiple data points on either side of the predicted regression parameter (GR_{50}/ED_{50}/LD_{50}). Dose-response studies on PPO-inhibiting herbicides where doses span only two orders of magnitude rarely achieved a full dose response, regardless of the herbicide applied or the timing of application. At least eight unique molecular assays have been developed to confirm resistance on *Amaranthus* spp alone. Molecular assays will continue to provide useful insights for future PPO-R research; however, no PPO-R molecular assay is ideal, and none are immune to inaccurate results, albeit some are more accurate than others. The *PPX2L* gene (the gene of interest for four of the known PPO-R mutations in *Amaranthus*) is characterized by highly variable introns (non-coding regions) and less variable exons (coding regions), either of which can create inherent challenges for molecular assays depending on the assay design. For example, there is SNP on exon 9 near the dG210 deletion recently described in 2020 that in theory could impact results of the widely used TaqMan assay. Researchers using molecular assays must take the inherent genetic variability into account when planning research and interpreting results as this can lead to inaccuracies in results of any SNP genotyping assay.

How Does Resistance to PPO-inhibitors Compare with Other MOA Resistance? Bryan G. Young*; Purdue University, West Lafayette, IN (227)

Herbicides inhibiting the protoporphyrinogen IX oxidase (PPO) enzyme have been commercialized for over 40 years, and were launched in the mid-1970s shortly after glyphosate. Weed resistance to PPO-inhibitors was not documented until 2001 in a population of *Amaranthus tuberculatus* (waterhemp) in Kansas. Since then, resistance to PPO-inhibitors has been confirmed in 12 other weed species, with a total of four species within the *Amaranthus* genus. Arguably, the most widespread resistance to these herbicides involves *A. tuberculatus* and *palmeri*, which are prevalent through the Midwestern and Midsouthern U.S. in soybean and cotton production. In the 1990s, the postemergence PPO-inhibitors in the diphenylether chemical family were being applied in soybean production to control waterhemp resistant to the ALS-inhibiting herbicides. The non-systemic nature of the PPO-inhibitors would commonly result in waterhemp survival if the target weed size was larger than ideal. Thus, weed survival following application of these herbicides to waterhemp was often noted as just adverse application conditions beyond the activity limits of the herbicides. Field identification of suspect herbicide-resistant weeds in the 1990s was the recognition of plants with no injury symptoms directly adjacent to plants of the same species that were completely dead. During this era observations such as these were common for target-site (TS) resistance to group 1 (ACCase), 2 (ALS), and 5 (photosystem II) herbicides, and were thought to be the norm associated with a high magnitude of resistance. Whole-plant dose response on the Kansas population demonstrated low-level herbicide resistance. Thus, the detection of biotypes resistant to PPO-inhibitors (PPO-R) was likely delayed, as failed weed control was attributed to the inconsistency of non-systemic, foliar herbicides. Ultimately, the resistance mechanism confirmed in the Kansas population was a rare codon deletion involving glycine at the 210th position (?210). Other resistance mechanisms documented for PPO-inhibitors include mostly TS mutations and at least one instance of metabolism-based resistance enabled by enhanced cytochrome P450 activity in Palmer amaranth. The interesting aspect for nearly all the TS resistance mechanisms confirmed is that the mutations occur on the PPX2 gene located in the mitochondria instead of the PPX1 gene located in the chloroplast, where the primary herbicidal activity is thought to occur. Thus, mutation of the PPX2 gene for resistance to PPO-inhibitors is assumed dependent on co-localization to have the PPO2 enzyme in the chloroplast. Similar to most forms of herbicide resistance, PPO-R weeds have not been associated with a clear fitness penalty. Furthermore, low-level resistance resulting from a TS mutation has now become more common and can be found in weeds resistant to glyphosate and ALS-inhibitors, with varying levels of cross-resistance among herbicide chemical families and within active ingredients within these chemical families. Perhaps one of the more unique differences associated with PPO-R *Amaranthus* has been that the low-level resistance mechanism allows for soil residual applications of flumioxazin, sulfentrazone, and fomesafen to remain active enough to justify their commercial use while foliar applications of these herbicides have limited activity. In fact, soil residual applications of flumioxazin and sulfentrazone are key herbicides mentioned by university specialists for waterhemp control, including those with confirmed resistance to PPO-inhibitors. The primary drawback is these residual applications still select for higher frequencies of the resistance allele in waterhemp plants that escape the soil residual herbicides. Thus, the soil residual PPO-inhibitors should not be applied as the only residual herbicide chemistry and should not be the focal herbicide of subsequent postemergence herbicide applications in the field. The fact that PPO-inhibitors can still provide commercial value for management of resistant biotypes is the foundation for new PPO-inhibitors and crop traits currently in development as future management tools.

PPO Biochemistry and Protein Structure as Tools for Optimizing New Herbicide Candidates and Resistance Research. Aimone Porri*[1], Rex A. Liebl[2], Raphael Aponte[1], Douglas A. Findley[3], Michael Betz[1], Jens Lerchl[1]; [1]BASF Corp, Limburgerhof, Germany, [2]BASF Corp, Raleigh, NC, [3]BASF Corp, Research Triangle Park, NC (228)

Since the commercial introduction of the PPO herbicide nitrofen in 1963, PPO inhibitors have been among the most intensively researched herbicides in crop protection with more than 100,000 compounds claimed in 5,000+ patents. Yet despite decades of focus by the ag chem industry, only about 30 PPO inhibitors have been commercialized with just a handful achieving major market success. Clearly, new approaches were needed to create the next generation of PPO herbicide. In 2004 the crystal structure of a PPO inhibitor in the plant PPO enzyme was published, thereby opening new avenues for the design of PPO herbicides. An example of such a structure-designed PPO inhibitor is Tirexor, a new herbicide by BASF Agriculture Solutions that provides excellent efficacy on targeted broadleaf and certain grass weeds. One important property of Tirexor is the newly introduced germinal difluoride group, that creates four additional polar enzyme backbone interactions, resulting in stronger binding of this inhibitor to the target and less sensitivity to resistance development by side chain variations. Tirexor is also able to control very problematic single and multiple herbicide-resistant weeds for different herbicidal modes of action, including PPO-resistant biotypes, such as ?G210, R128G, M, L and G398A *Amaranthus* target site mutants. Structural biology data, target site resistance data and resistance breaking performance of Tirexor in the field will be presented.

Herbicide Resistant Management Options Versus Mandatory Practices. A Stanley Culpepper*[1], Kevin W. Bradley[2], Bryan G. Young[3]; [1]University of Georgia, Tifton, GA, [2]University of Missouri, Columbia, MO, [3]Purdue University, Brookston, IN (229)

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. Achieving this goal will require maximized production levels and efficiency. Unfortunately, herbicide-resistant weeds pose a serious threat to production at an increasingly alarming rate. Implementing sound diversified herbicide programs coupled with cultural and/or mechanical tactics have proven effective in mitigating resistance across herbicide mechanisms of action (MOA). However, designing an effective program at the farm level requires an understanding of how each herbicide within a MOA performs. Protoporphyrinogen oxidase (PPO)-inhibiting herbicides are an ideal example of this challenge. Foliar applications of PPO-inhibitors on resistant populations of *Amaranthus* most often fail to result in effective control, with some differential response across active ingredients. Conversely, soil residual applications of fomesafen, flumioxazin, and sulfentrazone remain effective for control of these resistant populations, albeit with a shorter length of residual control while shifting towards a greater frequency of the resistant allele in any surviving weeds. Nonetheless, flumioxazin and sulfentrazone continue to be foundational soil residual herbicides for control of resistant populations. Although best management practices would dictate that another effective herbicide MOA with soil residual should be applied with these herbicides, and that alternatives to PPO-inhibitors should be the focus in subsequent postemergence applications. Although weed scientists work tirelessly to help farmers prevent, delay, and mitigate impacts from herbicide resistance, the current approach must be improved. Future success will require enhanced cooperative efforts of weed scientists with the Weed Science Society of America, the U.S. EPA, State Lead Agencies, Industry, and the USDA. These efforts must understand the importance of developing and implementing sound effective practices at the local level, eliminating the one-size-fits all approach. Equally important is the need for this group to foster access to funds provided through the Farm Bill. If farmers have access to these funds to conserve soil, why would funding designated for herbicide stewardship, which can reduce the need for tillage to control weeds, be unrealistic? Perhaps a tiered incentive program can reward farmers for implementing weed management strategies that integrate one or more practices that are non-chemical, or at least demonstrate that control of the majority of the weed population does not rely on any single herbicide active ingredient or MOA group. Similarly, farmers and farm managers must be amendable to making wise decisions when applying herbicides. Farmers overwhelmingly favor low-cost weed management to maximize profits, a strategy that readily translates to herbicides only, and as few herbicides as possible to kill weeds. Hence, the inevitable path towards herbicide resistance will only be re-directed if the economics of herbicide stewardship changes. If an effective cooperative solution cannot be achieved with these efforts, then the debate of mandatory resistance management programs is warranted. Within this debate, the influence of industry incentive programs often promoting only their own products must be scrutinized.

SYMPOSIUM - 3. OPTIMIZING INVASIVE AQUATIC PLANT MANAGEMENT, MONITORING, AND OUTREACH EFFORTS TO MEET REGIONAL NEEDS

Implementing Invasive Aquatic Plant Management Programs Within the California Regulatory System. A Case Study of the California Delta Program. John D. Madsen*; USDA-ARS, Davis, CA (230)

Lake Istokpoga: Addressing Complex Stakeholder Relations. Jason Ferrell*; University of Florida, Gainesville, FL (231)

Stakeholders concerned about the lack of submersed aquatic vegetation (SAV, primarily hydrilla [*Hydrilla verticillata* (L. F.) Royale] in Lake Istokpoga, FL, have hypothesized that legacy herbicides in sediments were the possible cause of reduced SAV growth for the past 3 yr. Bioassay experiments were conducted from sediments collected from nine stations located around Lake Istokpoga in areas identified by stakeholders in which hydrilla had previously grown. These were compared with sediments collected from three stations in similar Lake Tohopekaliga, FL, where hydrilla was currently growing. Tomato (*Solanum lycopersicum* L.) seeds were germinated in sediments from all stations in both lakes and control soils. Bare-root tomato transplants (3.8 cm tall) planted in sediments from both lakes continued to grow and, when harvested, plant dry weights were similar to transplants planted in two control soils (pure sand and 1 : 1 ratio potting soil : sand). Hydrilla tubers were also planted in sediments collected from three stations in both lakes and control soils. Tubers germinated in sediments from both lakes and control soils, and the percentage of germination was not significantly different between lake sediments and control soils. Sediment samples from all nine stations in Lake Istokpoga were sent to laboratories for chemical analyses of the nine aquatic herbicides used in Lake Istokpoga during the past 10 yr, and all results were "nondetect." Sixty cores were collected from areas with a history of hydrilla growth in Lake Istokpoga, and no hydrilla tubers were collected, suggesting little or no propagules are present for resumed growth of this SAV. Bioassays and sediment analyses indicate that legacy herbicides are not the cause of the decreased abundance of SAV in Lake Istokpoga.

Increased Invasiveness of Hybrid Species. A Case Study of Hybrid Watermilfoil. Ryan Thum*; Montana State University, Bozeman, MT (232)

Managers increasingly recognize that Eurasian watermilfoil (Myriophyllum spicatum, including hybrids with native northern watermilfoil, M. sibiricum) is genetically diverse, and that strains can differ in their growth, spread, impacts, and herbicide response. A practical challenge for Eurasian watermilfoil management is developing methods that assess genetic variation to predict how a specific watermilfoil population will respond to a proposed control tactic (e.g., a specific herbicide) before implementing management. In this presentation, I illustrate how we combine genetic survey and monitoring of invasive watermilfoil populations with field and laboratory studies of herbicide response to inform management. One significant finding of our genetic surveys is that a given strain can be found in more than one lake. For example, we found one hybrid strain in eight lakes across Michigan, and a laboratory fluridone assay identified this strain as resistant to 6ppb fluridone. Therefore, lakes with a high proportion of this strain of hybrid watermilfoil should not be targeted for control with 6ppb fluridone. In contrast, our fluridone assay identified several strains of watermilfoil that appear susceptible to 6ppb fluridone, and therefore lakes dominated by these strains would likely respond well to fluridone treatment. Identifying lakes that share strains can facilitate communication among stakeholders regarding management experiences on particular strains. Further, by prioritizing strains to target for herbicide studies, quantitative lab and field studies of herbicide response can inform management on multiple lakes containing a given strain.

Biology and Management of Flowering Rush in the Northern US. Ryan M. Wersal*; Minnesota State University, Mankato, Mankato, MN (233)

Flowering rush (*Butomus umbellatus* L.) is an emergent invasive plant that is native to Europe and Asia. Flowering rush was introduced into North America at La Prairie, Quebec, along the St. Lawrence River and was first documented in the United States in 1928. Since this time there have likely been several introductions as it is an attractive ornamental plant for water gardens. It has spread to the New York shore of Lake Champlain, Connecticut, the Great Lakes region of the Midwest, Idaho, Montana, Oregon, and Washington. Currently two karyotypes are invasive to North America: an asexually reproducing polyploidy (triploid) karyotype and a sexually reproducing diploid karyotype. The diploid populations can produce both seeds and rhizomes, but tend to have a lower tolerance to high nutrient levels and are more restricted in their range. Triploid populations form fewer seeds and bulbils. Diploid populations are found primarily in the eastern US and Great lakes regions and a higher proportion of triploid populations in the Midwest and western US. In Midwestern populations growth of triploid flowering rush begins in late spring with peak biomass achieved from July to August in most years. Most notably however is the abundance of vegetative buds produced throughout the year. Water depth is a major limiting factor in the distribution of triploid flowering rush within waterbodies, in that, as water depth increases aboveground and belowground biomass decreases. Historically, management of flowering rush has relied on foliar applications of imazapyr and/or mechanical harvesting. Neither method has resulted in acceptable control of this species. More recently, use patterns have been developed for the herbicide diquat, which has become the most reliable operational control method for triploid flowering rush. However, as this karyotype continues to spread in the Pacific Northwest, especially into large reservoir and river systems, management in flowing water becomes problematic. Research is ongoing to develop use patterns for diquat and other aquatic herbicides in these systems with high flow. Integrating physical barriers (bubble curtains) with diquat application has shown promise in reducing nuisance biomass. Although there has been considerable research conducted on triploid flowering rush, there remains a paucity of peer-reviewed studies devoted to the diploid karyotype.

Monoecious Hydrilla: Researching Plant Biology, Sensing Techniques, and Herbicide Optimization for Management in Disparate Systems. Robert J. Richardson*; North Carolina State University, Raleigh, NC (234)

Hydrilla [*Hydrilla verticillata* (L. F.) Royale] is one of the most important invasive aquatic weeds in the United States. There are currently three distinct biotypes present. Dioecious hydrilla was first introduced to Florida in the 1950's and has been most problematic in the southeastern US. A monoecious biotype was introduced to North Carolina and the Potomac River area in the 1970's. A more recent introduction of a third distinct biotype has occurred in the Connecticut River and this biotype has not been fully described. In order to optimize control of monoecious hydrilla, research was conducted on biotype biology, sensing techniques, and management options. Monoecious hydrilla can sprout from subterranean turions and form new turions in as little as five weeks with water temperature of 16 C or greater. It is extremely tolerant of temporal shading and sprouting turions can elongate for at least six weeks in the absence of sunlight. Management programs must interfere with hydrilla shoots before new turions are formed in order to achieve long term control. Effective management programs are also dependent on accurate mapping of infestations. Hydroacoustic sensing has proven very effective in detection and delineation of monoecious hydrilla and processed heat maps have been correlated with hydrilla biomass. With accurate mapping, herbicide treatment programs can be designed to control hydrilla with low treatment rates while minimizing off target injury. Herbicide programs can also be combined with stocking of triploid grass carp to improve cost effectiveness of hydrilla management in reservoirs.

Water Soldier in Canada: Development of Research and Management Programs to Address This Invader. Holly Simpson*; Ontario Ministry of Natural Resources and Forestry, Peterborough, ON, Canada (235)

Water soldier, *Stratiotes aloides* L (Hydrocharataceae) is a perennial aquatic plant, native to Eurasia, that was first observed in the Trent River, in Ontario in the fall of 2008. This was the first wild occurrence in North America. It has emergent and submersed growth forms that aggressively out-compete other aquatic plants and negatively impact the biodiversity of aquatic ecosystems it has invaded. Water soldier also poses a threat to navigation and recreation. At its peak, the infestation area was 190 ha (469 acres) and included large colonies and small satellite populations, encompassing an approximately 50km section of the river. The observed negative impacts prompted its inclusion on the Conference of Great Lakes and St. Lawrence River Governors and Premiers' “least wanted” aquatic invasive species list in 2013 as a priority species for prevention and response. Following this, the Ontario Ministry of Natural Resources and Forestry (MNRF) introduced new legislation that included prohibitions on the possession, sale, transport, and deposit of high risk invasive species such as water soldier to prevent new infestations. An inter-agency working group including MNRF, Parks Canada, Ontario Federation of Anglers and Hunters, Trent University, Ontario Ministry of Environment, Conservation and Parks, Lower Trent Conservation, United States Army Engineer Research and Development Center, Ontario Invasive Plant Council, and Invasive Species Centre was formed to help coordinate research, monitoring, eradication and prevention strategies, culminating in the development of an integrated management plan for water soldier in 2014 which outlines a combination of control approaches including both physical removal and herbicide treatments. Based on this plan, eradication measures were initiated in fall 2014, with an initial focus on preventing further downstream dispersal of the plants and expanding to address the source populations. Results indicate that this approach has been effective as the downstream spread has stalled and the infestation is greatly reduced. This presentation will provide an overview of the suite of actions undertaken to address the threat of water soldier to Ontario and the Great Lakes basin.

Aquatic Plant Management in Middle Earth. Development of Management Programs for Unique Environments in New Zealand. Deborah Hofstra*; National Institute of Water & Atmospheric Research Ltd, Hamilton, New Zealand (236)

New Zealand has a multitude of freshwater bodies and lakes, many of which are integral to its reputation as a land of scenic beauty and recreation. The native aquatic flora is relatively diverse with over 100 species recognised to date, most of which are low growing. However new invasive aquatic plants, introduced primarily through the ornamental and aquarium trade, have spread to large parts of the country. In 2009 approximately one-third of all surveyed lakes were impacted by one or more of the six worst invasive submerged weeds. The presence of invasive weed species invariably has a detrimental effect on native plant biodiversity, abundance and depth range in the short term, and on native seed banks in the longer-term. The displacement of native plant species represents a loss in habitat diversity for native animals. Effective invasive plant management relies on the development of appropriate tools and interventions to detect, and respond to new incursions and established invasive weeds. In particular, management programs benefit from early detection of invasive alien species (IAS), when the environmental and economic impacts of IAS can be minimised, and more control options are available. The selection of which tools or approaches to use in an aquatic plant management program (APMP) are largely determined by the outcome sought, such as eradication, nuisance control, or containment, the biology of the target species and site-specific criteria (e.g., water depth, access). This paper describes the development of APMP for submerged IAS in Aotearoa New Zealand, including recent science advances and case studies.

Aquatic Plant Management in the Victoria, Australia Irrigation System. Tony Dugdale*; Agriculture Victoria Research, Bundoora, Australia (237)

Irrigation channels provide water to 38% of Australian farms and deliver ~2,500 gigalitres of water via ~7,500 km of earthen irrigation channels. Delivery of this water is often obstructed by aquatic weeds that infest these channels. The most troublesome submersed weeds are the native species *Vallisneria australis* and *Potamogeton* spp., along with *Elodea canadensis* to a lesser degree. All are routinely controlled to restore flow-capacity with the herbicide acrolein, winter dewatering and/or mechanical excavation. Acrolein is effective on a wide range of species, but it only provides short term control and is very toxic to fauna and dangerous to people when applying it. Dewatering and mechanical removal can be effective, but they are difficult to manage, costly and dewatering has become less common due to water saving measures. A substantial body of research has recently been completed to develop endothall as a new tool for submersed weed control in Australia, culminating in successful demonstration trials in 25 km of irrigation channels. A range of emergent weeds are also problematic, particularly *Sagittaria platyphylla* along with native *Typha* and *Phragmites* spp. These are managed via glyphosate and occasional use of imazapyr. The limited range of herbicide options registered for use in irrigation water presents challenges exemplified by the recent invasion of Egeria densa into Victorian channels. I will describe what is known of its invasion, impact and a research project to test management options for it.

SYMPOSIUM - 4. BEYOND THE BOOM – BENEFITS OF WEED AND BRUSH MANAGEMENT IN GRASSLANDS

Beyond the Boom – Benefits of Managing Weeds and Brush in Grasslands. Morgan Treadwell*; Texas A&M AgriLife Extension, San Angelo, TX (274)

Managing for encroaching brush and invasive weeds is an important strategy to enhance overall grassland productivity, function, resiliency, resistance, and integrity. Maintaining grazable acres of forage produced by those grasslands are the foundation upon which livestock performance, profitability and sustainability are optimized. Listening to both above and below ground signs of health, function, and working processes ensures a grassland's resiliency to thwarting off monocultures of undesirable, unpalatable, and often non-native brush and weed species. Furthermore, keeping brush and weeds from choking out grasslands, allows scientists to form a deeper and meaningful understanding of how grasslands serve as workhorses for microbial communities, maintain deep and functioning root systems during aboveground disturbances, and how grasses rapidly transition dormant bud reserves into active meristematic tissue. But sometimes ranchers and managers get bogged down and fail to see beyond the boom, only attempting to manage brush and weeds after pasture productivity is already compromised and brush is mature and dense, essentially buying pastures back from invasive species. William Bray stated in his 1904 report *The Timber of the Edwards Plateau of Texas* "This struggle of the timberlands to capture the grasslands is an old warfare....it spreads like infection." This trend is true today and especially pronounced in the Great Plains, where only half of the Great Plains' original grasslands remains intact. Species like honey mesquite (*Prosopis glandulosa*), honey locust (Gleditsia triacanthos), black locust (Gleditsia triacanthos), sumac (*Rhus spp.*), dogwood (*Cornus spp*.), post oak (*Quercus stellata*), elm (*Ulmus spp.)* salt cedar (*Tamarix ramosissima*), huisache (*Acacia smallii*), Eastern redcedar (*Juniperus virginiana*), redberry juniper (*Juniperus pinchotii*), pricklypear (*Opuntia engelmannii*), sericea lespedeza (*Lespedeza cuneata*), and many other species represent alarming rates of spread and rapid establishment throughout Great Plains grasslands. Although, these species and others represent a significant challenge, they also present great opportunity for managers, researchers, and Extension specialists. Now, more than ever, grasslands –working lands- need collaborative research efforts conducting sound and applied science that is just as relevant to the rancher as it is the peer-reviewed journal. This symposium will highlight the value of managing weeds and brush to prevent toxic plant establishment, enhance livestock performance, increase forage productivity, the integration of new technology, and how to communicate results and strategies more effectively so that stakeholders understand approaches well enough to implement on their own. More importantly, stakeholders that depend on grasslands will learn sound strategies that build upon grassland function and integrity, and not deplete it. Whether it's conducting research or rotating cattle, managing for weeds and brush in grasslands turns everyone into stewards. And it takes a steward's commitment to maintain open spaces, to integrate a multi-faceted approach, and to consistently manage for encroaching brush and opportunistic weeds in vulnerable grasslands. Morgan.Treadwell@ag.tamu.edu

Realizing the Value of Managing Weeds and Brush in Conservation Grassland Sites. Mark J. Renz*; University of Wisconsin - Madison, Madison, WI (275)

Grasslands are a major global ecosystem, providing key ecosystem services that many annual agronomic systems do not. While these lands are utilized primarily for forage and livestock production, a growing percentage of grasslands are managed for conservation. Goals within conservation grasslands include maintaining/enhancing plant biodiversity, hydrology, wildlife habitat, soil/nutrient retention, and carbon storage. Despite the lack of production goals in most conservation grasslands, these lands benefit from management of undesirable weeds and brush as they disrupt ecosystem processes sought to be conserved or enhanced. Examples include detrimental impacts to plant biodiversity, wildlife, nutrient cycling, nutrient loading and soil erosion. Fortunately, removal of unwanted plants can restore critical ecosystem processes. Management methods utilizing fire, mowing, targeted grazing and herbicides have been shown to be effective, especially if conducted prior to widespread distribution of undesirable weed and brush populations. Traditionally conservation grasslands have been minimally managed for weeds and brush until populations are widely distributed and difficult/costly to manage. We recommend a proactive approach, where weed and brush management occurs at the early stages of invasion, ensuring that undesirable plants do not establish large populations. This proactive approach will better facilitate the managers' goals for conservation grasslands and prevent the development of weed and brush populations that are too time-consuming and expensive to control. mrenz@wisc.edu

Toxic Plants in Grasslands and the Impact on Livestock. Catherine Barr*; Texas A&M Veterinary Medical Diagnostic Lab, College Station, TX (276)

Grasslands are critical infrastructure for most cow/calf operations. The quality and abundance of pasture grasses directly influence livestock rate of gain, thereby affecting livestock margins and production costs, which determine the profitability of a stocker operation. The successful cattleman controls weeds not only to preserve healthy pasture but also to prevent plant poisonings that may reduce individual animal performance or even cause fatalities. Extension programs for Integrated Toxic Plant Management (ITPM) have been developed to teach ranchers to identify the potentially toxic plants in their pastures, understand symptoms of plant poisonings in livestock, recognize biomes where certain plants are likely to emerge, and provide strategies for controlling those plants and their ingestion. Toxic plants across the US cause a range of effects in cattle and other grazing species. Nightshades (*Solanum* spp.) can cause gastrointestinal irritation (diarrhea) and neurological problems (incoordination, depression) when overconsumed. Starthistles (*Centaurea* spp.) cause a very specific brain damage in horses, preventing them from chewing and swallowing properly. Coffee senna and its cousins (*Senna occidentalis*, et al.) cause profound skeletal muscle destruction in cattle (alert downers) and heart muscle damage in goats and chickens. Some plants cause birth defects in calves and lambs [e.g., skunk cabbage (*Veratrum* spp.), tobaccos (*Nicotiana* spp.), larkspurs (*Delphinium* spp.)]. Plants that contain pyrrolizidine alkaloids (e.g., *Amsinckia* spp., *Crotalaria* spp., *Heliotropium* spp., *Senecio* spp.), cause a progressive liver damage that can take 6 weeks to over a year to kill animals that consume them. Every year we lose an unknown number of animals across the country to largely preventable plant intoxications. acbarr@tvmdl.tamu.edu

Livestock Performance Benefits as A Result of Managing Weeds and Brush in Grassland.
Jose Debeux*; University of Florida, Marianna, FL (277)

Weed encroachment in grasslands might result in large economic losses to livestock enterprises. They compete with forage species for light, water, and nutrients, reducing forage production. If water is a limiting factor, for every ton of C_3 weeds we lose 2-3 tons of C_4 grasses (e.g. bermudagrass, *Cynadon spp*.), considering that C_4 grasses are more efficient using water than C_3 plants. Weeds can also negatively affect grazing behavior, reducing voluntary forage intake and the proportion of forage utilization, resulting in reduced stocking rates. Voluntary intake is affected mainly because of reduced bite mass. Because of competition for light and nutrients, weeds can negatively affect forage nutritive value, reducing average daily gain. Stocking rate and average daily gain are the major drivers of animal output per area. Reducing those two key components will drastically affect animal performance per area. Managing weeds on grazing lands is key to enhance cattle productivity. Grazing management can be a powerful tool to reduce weed infestation, but once weeds are established, they will need to be controlled. Reducing weed encroachment will increase forage productivity and will benefit forage intake and animal performance. In addition to curbing livestock performance, some weeds can be poisonous for cattle. Some weeds have thorns that not only hurt the animals but also depreciate the value of the leather or even hurt the udder and teats of lactating cows, potentially causing mastitis and loss of productive potential. Brushes are highly invasive and once they establish, they take advantage in terms of light competition with herbaceous forages. Their deep root system brings ecological advantages to compete with grasses. Weed and brush encroachment also depreciate the land value and, as they expand, they get more costly to control. Managing weeds and brush in a grassland is perhaps one of the most important and foremost management practices to increase animal performance and profitability of livestock production systems. Identifying the problematic weeds and using the right management option is key to reduce costs and enhance success of this practice. dubeux@ufl.edu

Forage Response and Economic Benefits of Weed and Brush Management in Grasslands.
Scott Flynn*[1], Byron B. Sleugh[2]; [1]Corteva Agriscience, Lees Summit, MO, [2]Corteva Agriscience, Carmel, IN (278)

A common question among managers of grazing operations is "At what level of weed pressure does it become economical to apply herbicides on pastures?" Unfortunately, there isn't just one answer to this question as production goals and practices differ between operations and even within an operation over time. Regardless, the real question being ask is if weed control will increase profit per acre. There are three basic avenues that may be taken to improve profit per acre through weed control. The first is to increase the carrying capacity of the grazing operation by controlling weeds and replacing those weeds with desirable forage species capable of increasing the carrying capacity. The second is to use weed control to improve forage availability to the existing herd to support higher average daily gains (ADG), improve body condition (BCS) or extending the grazing season. The third is to simply improve animal health through controlling toxic plants that may suppress animal performance or increase mortality. When trying to determine the economic weed threshold in pastures several estimates or assumptions must be made. One of the most important is that weeds are displacing desirable forages and once controlled they will be replaced by these desirable forages. Normally we assume that for every pound of weeds we control we gain a pound of forage. However, we must keep in mind that this may vary among weed and forage species. Expected feed conversion of pasture forage species is also an important variable that must be considered. This number depends on forage quality, abundance, and management, but it is generally accepted that it takes 7-15 lbs DM to increase live weight by 1 lb. Grazing operations also differ in their level of forage utilization which is key in determining how efficiently the increase in forage production will be used. For instance, continuous grazing systems may only utilize 40-45 percent of available forage produced over the season were rotational grazing systems may reach 70% utilization. Thus, rotational grazing systems can't tolerate as much weed pressure as continuous systems as it will have a greater effect on carrying capacity. The number years between applications may vary between producers and products used, so this time frame must be considered in order to determine how cost will be spread out over months or years. For example, the use of non-residual herbicides such as 2,4-D only kills emerged weeds and will likely require more frequent applications than a residual pasture herbicide which may control certain weeds for several months. Efficacy of weed control over this time period is also important as we don't always expect 100% control, especially when we use non residual herbicides. Herbicide costs will vary as well depending on the weed spectrum. Herbicide costs may range from $8/acre for general broadleaf weed control to over $50/acre for dense brush. Other important variables are: profit per lb of beef sold, the level of forage DM production, and the level of forage utilization. Scott.flynn@corteva.com

New Technology to Enhance Management of Weeds and Brush in Grasslands. Charles Hart[1], Brett Martin*[2]; [1]Corteva Agriscience, Abilene, TX, [2]Corteva, Indianapolis, IN (279)

Globally it is estimated that only ~5% of grasslands are actively managed. Lower productivity relative to farmland or forest land means there's less money to spend on management. Therefore, a cost-effective solution that can quickly process large areas of land is needed to make management a more widely adopted practice. Only in the past few years has the availability of affordable, high spatial- and temporal-resolution imagery become a reality through new satellite providers. Coupled with rapidly decreasing costs in high-performance computing that is necessary to process such large imagery data sets, grassland management through highly accurate classification maps has become much more feasible. In the southwestern United States, honey mesquite (*Prosopis glandulosa)* is a highly invasive tree spread across much of Texas' grassland. In the United States, more than 70% of mesquite is found in Texas; more than 1/3 of Texas (>55,000,000 acres) has some level of mesquite cover; and more than 16,000,000 acres are so infested (>30-40% mesquite cover) as to have lost most of their grass production. Traditionally, treating mesquite has been difficult for several reasons: the sheer size of ranches often made it impractical to know exactly where to treat; specific environmental conditions need to be met for treatment to be effective; and mesquite has many physiological traits that mean it can often survive herbicide treatments. LANDVisor™, an integrated management solution developed by Corteva Agriscience, with honey mesquite as its first focus. LANDVisor combines satellite and aerial imagery, field data (environmental variables and field data for image classification), industry-leading technology and software solutions, and expert guidance to provide actionable insights to ranch owners and land managers. LANDVisor insights include where to spray and where not to spray - such as areas with desirable species or water. LANDVisor also shows ranchers their return on investment through potential forage and animal unit year (AUY) gains in treated areas. Most importantly, several key factors that influence when mesquite will be most susceptible to herbicide treatment can be monitored using LANDVisor. Treated areas are monitored post-application to measure efficacy. Research is ongoing to target other non-desirable species such as western honey mesquite (*Prosopis glandulosa* Torr. var. torreyana (Benson) M.C. Johnst.), prickly pear (*Opuntia spp*.), and huisache (*Acacia smalii* Isely). With LANDVisor, landowners will have the confidence that they can manage their lands for their desired land cover conditions and get insights on the potential return on their investment. Brett.martin@corteva.com ™®Trademarks of Corteva Agriscience and its affiliated companies.

If We Build It, Will They Come? Challenges, Opportunities, and Needs in Weed and Brush Management Research in Grasslands. Daniel Tekiela[1], Byron B. Sleugh*[2]; [1]University of Wyoming, Laramie, WY, [2]Corteva Agriscience, Carmel, IN (280)

Grasslands are the foundation upon which livestock performance, ranch profitability, livestock farmer sustainability and subsistence are built. United Nations Food and Agriculture Organization states that grasslands occupy 27% of land area and 70% of agricultural land area globally. These grasslands are the basis for forage-livestock systems, conservations systems, recreational activities and a myriad of ecosystem functions or benefits and varying levels of management or management inputs. These activities and interactions can result in invasion and increased abundance of weeds and brush which can hinder attainment of management objectives. Even though grasslands account for most agricultural lands globally, research funding and focus on the impact of weeds and brush or vegetation management impacts significantly lags agronomic or arable crops. This presentation will highlight key points from other symposium speakers then focus on the needs, challenges, and opportunities that lie ahead. Topics to be covered by other speakers include - benefits of managing weeds and brush in grasslands; realizing the value of managing weeds in conservation grasslands; toxic plants in grasslands and their impact of livestock; livestock performance, forage response and economic benefits of weed and brush management in grasslands; new technologies to enhance weeds and brush management. Byron.sleugh@corteva.com

SYMPOSIUM - 5. ADVANCES IN SENSOR-BASED WEED DETECTION AND PRECISION MANAGEMENT

Precision Weeds Technologies: A Multi-national Effort to Automate Sensing Weed Species, Density, Cover, and Biomass for Researchers and Farmers. Steven Mirsky*; USDA-ARS, Beltsville, MD (299)

Computer vision and machine learning technologies that can detect weeds, identify them by species and performance (density, size, and biomass), and produce maps are critical to advance integrated weed management research and practice. To accelerate innovation from the research community and broad-scale adoption by growers, these technologies need to be low-cost and openly accessible. The Precision Sustainable Agriculture (PSA) and GROW (Getting Rid of Weeds) teams specialize in developing and regionalizing digital tools for automated data acquisition, real-time analysis, and visualization for field researchers, practitioners, and producers. These teams are using computer vision and artificial intelligence to effectively estimate weed species, density, and biomass that can be used in small-plot and on-farm research. These measurements are typically labor-intensive, inconsistent across studies, and small in scale. Weed distribution is also very patchy, limiting applicability of discrete, small-scale sampling to broader field-scale distribution. Our network is distributed across US soybean, corn, and cotton production acreage, which enables the unique development and beta-testing across a broad spectrum of climate, soil, and management systems. This presentation will review the suite of technologies being developed by PSA and GROW, their current deployment, and future activities. The ability to rapidly identify species and estimate weed densities and biomass production with sensing technology will expand the development of new precision weed management tactics and technologies to address the herbicide-resistant weed epidemic.

Machine Learning for Weed Detection and Classification: Applications in Weed Ecology and Precision Management. Muthukumar V. Bagavathiannan*[1], Chengsong Hu[1], Bishwa B. Sapkota[1], Matthew Kutugata[1], Steven Mirsky[2]; [1]Texas A&M University, College Station, TX, [2]USDA-ARS, Beltsville, MD (301)

Recent advancements in artificial intelligence and machine learning offer great potential for improving agricultural production and sustainability. Application of these tools and techniques, however, has been very limited in the agriculture domain, particularly in weed management. In addition to precision management, these digital tools have tremendous applications in studying weed biology and ecology. In particular, measurements such as weed seedling emergence counting, weed density and biomass estimation, weed-crop competitive interactions, crop yield prediction, seedbank addition potential from weed escapes, etc. can be determined using digital tools. In this regard, an ability to effectively detect and map weeds under field conditions is an important requirement for the application of these technologies. Vegetation indices such as the excess green index (ExG) and the normalized difference vegetation index (NDVI) are shown to be effective in weed mapping under different situations; however, vegetation indices are usually not robust for species-specific detection and mapping of weeds in mixtures. Convolutional neural networks (CNNs) offer a more effective means for plant species detection. Synthesis of artificial images speed up the training of prediction models, and address the need for volumes of annotated image data. In addition to 2D, 3D image analysis approaches are also being investigated to facilitate improved detection and estimation of plant characteristics.

3D Mapping of Weeds for Weed Biomass Estimation. Paula Ramos Giraldo*; North Carolina State University, Raleigh, NC (302)

Multiple herbicide-resistance (MHR) is causing farmers to return to tillage and complex tank mixes for weed management, compromising advances in soil conservation and water quality achieved over the past three decades through the widespread adoption of conservation tillage. Our goal is to use recent advancements we have made in 3-dimensional (3D) imaging to characterize vegetation for building precision integrated weed management (IWM) solutions and to prevent reversion to tillage-based weed control. We have developed an algorithm for 3-D reconstruction using Structure from Motion (SfM). This 3-D computer vision system uses real-time two-dimensional RGB video from adventure cameras (GoPros) to render 3-D imagery of field plants to identify weeds vs cash crops and estimate their biomass. We have also generated a non-SfM approach that utilizes a stereoscopic camera (OAK-D) combined with the OpenCV libraries for computer vision and Intels distribution of the OpenVINO toolkit for using deep learning algorithms on microprocessors. In both approaches, we use a semantic segmentation mask to differentiate broadleaves, grasses and soil and layer that information on top of the depth maps. The depth maps are analyzed with a combination of principal components analysis (PCA) and multiple regression to predict plant volume and then, through correlations, predict biomass for each class of weed. Determination coefficients between 0.5 and 0.8 show the potential of this approach to measure the biomass of the weeds present in our fields. In future work, we intend to improve the accuracy of depth measurement using real-time analysis on small field computers.

Hyperspectral Imaging for Weed Species Detection and Herbicide Resistance Monitoring In-crop. Prashant Jha*; Iowa State University, Ames, IA (303)

Hyperspectral imaging is a segment of the field of precision agriculture that can be used to accurately and quickly map different weed species and, more specifically, herbicide-resistant vs. herbicide-susceptible weed biotypes in crop fields using advanced optics and machine learning algorithms. We demonstrated the ability to distinguish between different types of herbicide resistance in kochia (*Bassia scoparia* L. A. J. Scott), specifically glyphosate and dicamba resistance. This method involves extracting reflectance information from the images as features, training a neural network to differentiate species and herbicide resistance (biotypes) at various points in the crop or weed lifecycle, and then utilizing the trained network with images captured from the field to discriminate herbicide-susceptible from herbicide-resistant weed biotypes at the optimal lifecycle stage. Imaging was conducted using both ground-based and drone-based hyperspectral imagers. Depending on what plants were imaged, the age of the plants, and lighting conditions, the classification accuracies were up to 99% for spectra acquired on a ground-based imaging platform and close to 80% on a drone-based platform. These accuracies were generally highest when imaging younger plants of the weed species, which would be an ideal scenario for early detection and resistance monitoring in crop production fields.

A Weed Recognition System That Enables In-crop Physical Weed Control in Australian Cropping Systems. Michael J. Walsh*[1], Guy Coleman[2]; [1]University of Sydney, Narrabri, Australia, [2]University of Sydney, Camden, Australia (304)

In Australian cropping, the demand for alternative weed control technologies is being driven by widespread herbicide resistance and the loss of effective weed control. Although there are numerous non-chemical weed control options, they cannot be used for selective in-crop weed control without site-specific targeting technologies. The precise application of weed control treatments requires accurate weed recognition system that enables the specific targeting of weeds within the complex environment of large-scale cropping systems. The level of weed recognition accuracy that enables within-crop targeting requires a sophisticated machine-learning (ML) approach. To facilitate deep neural network-based learning for weed recognition, several thousand images of rigid ryegrass (*Lolium rigidum*) and turnip weed (*Rapistrum rugosum*) were routinely collected within crops throughout two winter crop growing seasons. These images were used to establish recognition algorithms for each weed species based on pixel-wise semantic segmentation. Their accuracy was field tested with a physical weed control capable autonomous, robotic platform. Average rigid ryegrass recognition accuracy of 61 and 46% was achieved in wheat and chickpea crops, respectively. Turnip weed recognition accuracy was consistently higher at 76 and 81% in wheat and chickpea crops respectively. This research highlighted the difficulty of accurately identifying weeds in cropping situations with limited weed image data sets as well as the laborious nature of pixel-wise annotation, particularly when there are similar plant morphologies. Further research efforts have focussed on substantially increasing the number of high quality and labelled weed images, particularly of rigid ryegrass in cropping fields, for the development of more accurate recognition algorithms. These collected and annotated weed images are now the basis of a crop-weed database, WeedAI, that has been established using structures and standards for crop-weed image storage. The role of this publicly available database is facilitating the development of weed recognition algorithms by providing access to quality weed images.

Precision Weed Management with UAVs and Ground Robots. Vijay Singh*[1], Daniel E. Martin[2], Muthukumar V. Bagavathiannan[3]; [1]Virginia Tech, Painter, VA, [2]USDA-ARS, College Station, TX, [3]Texas A&M University, College Station, TX (305)

Recent advances in imaging sensors and unmanned aerial systems (UAS) have improved the efficiency of precision weed management. Along with collecting image data, UAS have the potential to be used for herbicide spray applications. Herbicides are relied upon as an important tool for weed management in row-cropping systems. Studies have been conducted in 2018 and 2019 to standardize flight altitude, nozzles and spray volume for UAS-based POST herbicide spray applications. Herbicide (glufosinate) was applied as early- and late-POST treatment. Results of spray pattern have indicated that three-meter flight altitude had lowest coefficient of variation compared to two-, and four-meter altitude. UAS-based herbicide applications provided 100% weed control even at a low spray volume of 18.7 L ha^{-1} (2 GPA) compared to 75% control with backpack sprayer at 140 L ha^{-1} when applied at late-POST stage. Early-POST applications have indicated similar efficacy when applied with UAS at 18.7 and 37.4 L ha^{-1}, and with backpack sprayer at 140 L ha^{-1}. However, nozzle selection played key role in improving the herbicide efficacy of UAS-based spray applications. The percent of spray droplets on the abaxial surface for the UAS at 37.4 L ha^{-1} was 4-fold greater than that for the backpack sprayer at 140 L ha^{-1}. The increased spray deposition on the abaxial leaf surfaces was likely caused by rotor downwash and wind turbulence generated by the UAS which caused leaf fluttering. Greater deposition was observed with UAS on foliage/area inaccessible with backpack sprayer due to overlap of plant leaves. UAS-based imagery and spray applications can address primary agricultural challenges but more research is required on understanding and optimizing the operational conditions.

Spray Drift Characterization of Hydraulic Nozzles for Remotely Piloted Aerial Application Systems. Daniel E. Martin*; USDA-ARS, College Station, TX (306)

Automated Weed Removal in Vegetable Crops. Steve Fennimore*; University of California - Davis, Salinas, CA (307)

Most vegetable crops lack an adequate selection of herbicides to protect them from weed losses. Therefore, the high standards for weed control in vegetable crops require that growers practice integrated weed management using combinations of cultural, physical, and chemical weed control tools. Hand weeding is among the more important physical control tools. Dependence of vegetable crop producers on labor for hand weeding places them in a precarious position due to labor shortages and high costs. Labor costs along with higher cost of complying with environmental, labor and food safety regulations have created an overwhelming need to find ways to improve labor use efficiency. As a weed scientist who works on vegetables, I have focused on improving hand-weeding efficiency. There are two types of weeders on the market currently, tractor towed and autonomous. The first machines that were introduced about 12 years ago such as the Garford Robocrop, Steketee, and Robovator worked by detecting the row pattern. These machines require space around the crop plant so that they can distinguish the individual crop plants that allows them to detect the plant row. Upon detection of the plant rows and individual crop plants in the row, cultivators like the Robovator can perform intra-row weeding with cultivator knives. These pattern recognition machines do not work well under high weed populations because they cannot differentiate crops from weeds. However, under most conditions they remove about half of the intra-row weeds and reduce hand-weeding times by about one third. Generally, these cultivators do not injure the crop or reduce yields. Recently, two autonomous weeders, the Farmwise “Titan” and Naďo “Dino” became available in Arizona and California. Farmwise is a company from San Francisco, CA and Naďo is from Escalquens, France. The Farmwise machine uses machine vision and algorithms to recognize weeds. The Naďo machine uses GPS guidance and fingerweeders to remove intra-row weeds. Trials were conducted with two autonomous weeder machines: three trials with the Dino robotic platform (NAĎO Corp) equipped with finger weeders and five with the Farmwise Titan weeder equipped with paired knives that open and close depending on position relative to the crop. All trials were replicated 3 to 4 times and arranged in a randomized complete block design. The autonomous cultivators were compared with standard cultivators that left a noncultivated10 cm-wide band around the seedline. Counts of pre and post-cultivation weeds were made in a 15 cm wide band centered on the seedline to determine the efficacy of cultivation. Hand weeding by commercial crews was timed and harvest evaluations were conducted. Initial weed populations had the most influence on time of hand weeding regardless of cultivator tested. The Dino was equipped with finger weeders and removed more weeds from the seedline than standard cultivation. Dino reduced weeding times 14 to 27%. The Titan cultivator removed a higher percentage of weeds from the seedline and reduced subsequent hand weeding time in most trials. The initial weed pressure determined the amount of hand weeding time; more time was required to hand weed fields with higher initial weed populations. Neither cultivator injured lettuce or reduced lettuce yield. Vegetable crops need automated weeding technology to reduce need for handweeding. These crops have the economic base to support a market for these weeding machines and for this reason are a center of innovation independent of traditional agricultural chemical companies.

Precision Weed Management in Florida Vegetable Production. Nathan Boyd*[1], Arnold W. Schumann[2], Shaun M. Sharpe[3]; [1]University of Florida, Balm, FL, [2]University of Florida, Lake Alfred, FL, [3]Agriculture and Agri-Food Canada, Saskatoon, SK, Canada (308)

Weeds occur in non-uniform patches in commercial vegetable fields, but herbicides are typically broadcast over the treated area or applied in uniform bands. Herbicide applications only where weeds occur has the potential to reduce herbicide usage without a reduction in efficacy. Several different artificial neural networks (ANN) have been evaluated for weed detection and identification and subsequently incorporated into smart sprayers for precision herbicide application in a variety of vegetable crops grown at the Gulf Coast Research and Education Center in Wimauma, Florida. Weed detection in field conditions has ranged from 50 to greater than 90% accuracy and herbicide usage in some trials decreased by 50-70%. Supplemental light general improved weed detection accuracy but detection accuracy decreased as tractor speed increased from 0.8 to 2.4 km/hr. This limitation is due in part to programming of the controller which we have modified to ensure accurate detection at higher speeds. Future work will focus on model improvement and evaluation of nozzle configuration to maximize efficiency. Smart sprayers equipped with ANN's can be used to accurately apply herbicides only where weeds occur within vegetable crops in Florida.