NCWSS
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The program and abstracts of posters and papers presented at the annual meeting of the North Central Weed Science Society are included in this proceedings document. Titles are listed in the program by subject matter with the abstract number listed in parenthesis. Abstracts are listed in numerical order followed by the author and keyword listing.

PROGRAM

PROGRAM

2017 Officers/Executive Committee

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General Session

Lewis and Clark Expedition: Soldiers as Scientists. Erin Hilligoss-Volkmann*1, Paul Rosewitz2; 1National Park Service, St. Louis, MO, 2National Archives and Records Administration, St. Louis, MO (116)

Managing Herbicide Resistance: Listening to the Perspectives of the Practitioners. Jill Schroeder*1, David R. Shaw2, Michael Barrett3, Harold Coble4, Amy Asmus5, Raymond Jussaume6, David Ervin7; 1USDA Office of Pest Management Policy, Washington, DC, 2Mississippi State University, Mississippi State, MS, 3University of Kentucky, Lexington, KY, 4North Carolina State University Professor Emeritus, Raleigh, NC, 5Asmus Farm Supply, Inc., Rake, IA, 6Michigan State University, East Lansing, MI, 7Portland State University, Portland, OR (117)

Washington DC Report. Lee Van Wychen*; WSSA, Alexandria, VA (118)

NCWSS Presidential Address. Gregory K. Dahl*; Winfield United, River Falls, WI (119)

Remembering Former NCWSS Members and Friends. Chris Kamienski*; Monsanto Company, Washington, IL (120)

Announcements. Christy L. Sprague*; Michigan State University, East Lansing, MI (121)

POSTER SECTION

***PRESENTER † STUDENT POSTER CONTEST PARTICIPANT**

Agronomic Crops I - Corn

†Residual Herbicide Activity as Influenced by Application to Soil Covered with Crop Residue. Ethan Johnson*[1], Brent Heaton[2], Mark Bernards[1]; [1]Western Illinois University, Macomb, IL, [2]Western Illinois University, Industry, IL (68)

Influence of Fall Establishment and Spring Termination Timings of Annual Ryegrass on Corn Yields. Taylor Campbell*[1], Joe Ikley[2], Bill Johnson[3]; [1]Purdue University, Lafayette, IN, [2]Purdue University, West Lafayette, IN, [3]Purdue University, W Lafayette, IN (69)

†Impact of Cover Crop Species Selection on Soil Moisture and Corn Development in Semi-Arid Rainfed Cropping Systems of Western Nebraska. Alexandre T. Rosa*[1], Liberty Butts[2], Cody Creech[3], Roger Elmore[1], Daran Rudnick[4], Rodrigo Werle[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska Lincoln, North Platte, NE, [3]University of Nebraska-Lincoln, Scottsbluff, NE, [4]University of Nebraska-Lincoln, North Platte, NE (70)

Effects of Timing of Weed Removal and PRE Herbicides on Growth and Yield of Corn. Ayse Nur Ulusoy*[1], O. Adewale Osipitan[2], Jon E Scott[3], Stevan Z. Knezevic[2]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Concord, NE, [3]University of Nebraska, Concord, NE (71)

†Postemergence Herbicides for Weed Control in Organic Corn and Soybeans. Betzabet Valdez*[1], Reid Smeda[2]; [1]University of Missouri, Columbia, Columbia, MO, [2]University of Missouri, Columbia, MO (72)

†Weed Control Following Single-Pass PRE or POST Corn Herbicides as Affected by Planting Date. Luke Merritt*[1], Brent Heaton[2], Mark Bernards[1]; [1]Western Illinois University, Macomb, IL, [2]Western Illinois University, Industry, IL (73)

†Management of Palmer Amaranth Using a Premix of Dicamba and Tembotrione in Corn. Amy D. Hauver*[1], Parminder Chahal[2], Kevin Watteyne[3], Amit J. Jhala[2]; [1]University Nebraska Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]Bayer CropScience, Lincoln, NE (74)

†POST Corn Herbicide Options for Control of Glyphosate-Resistant Palmer Amaranth in Western Nebraska. Clint W. Beiermann*[1], Nevin C. Lawrence[1], Stevan Z. Knezevic[2], Amit Jhala[3], Cody Creech[1]; [1]University of Nebraska-Lincoln, Scottsbluff, NE, [2]University of Nebraska-Lincoln, Concord, NE, [3]University of Nebraska-Lincoln, Lincoln, NE (75)

†Corn Barrier Effect on Herbicide Drift. Bruno Canella Vieira*[1], Thomas R. Butts[2], Andre O. Rodrigues[2], Kasey Schroeder[2], Jeffrey Golus[2], Greg R Kruger[3]; [1]University of Nebraska, Lincoln, NE, [2]University of Nebraska-Lincoln, North Platte, NE, [3]University of Nebraska, North Platte, NE (76)

Agronomic Crops II - Soybeans

†Optimizing a Cover Crop Program for the Control of Glyphosate-Resistant Horseweed. Alyssa Lamb*[1], Mark Loux[2]; [1]The Ohio State University, Columbus, OH, [2]Ohio State University, Columbus, OH (77)

†Weed Management in Soybean Intercropped with Spring Planted Rye. Zachary Brewer*[1], Brent Heaton[2], Mark Bernards[1]; [1]Western Illinois University, Macomb, IL, [2]Western Illinois University, Industry, IL (78)

†Integration of Residual Herbicides and Cover Crops for Weed Control in a Soybean Production System. Derek Whalen*, Mandy Bish, Kevin W Bradley; University of Missouri, Columbia, MO (79)

†Combining Herbicide Programs and Cereal Rye Cover Crop for Integrated Weed Management in Soybeans. Adam Striegel*[1], Liberty Butts[2], Nikola Arsenijevic[3], Gustavo Vieira[3], Alexandre T. Rosa[1], Christopher Proctor[1], Rodrigo Werle[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska Lincoln, North Platte, NE, [3]University of Nebraska-Lincoln, North Platte, NE (80)

Effects of Timing of Weed Removal and PRE Herbicides on Growth and Yield of Soybean. Pavle Pavlovic*[1], Amit Jhala[2], Ethann R. Barnes[2], Clint Beiermann[3], Nevin C. Lawrence[4], Jon E Scott[5], O. Adewale Osipitan[1], Stevan Z. Knezevic[1]; [1]University of Nebraska-Lincoln, Concord, NE, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]University of Nebraska, Scottsbluff, NE, [4]University of Nebraska-Lincoln, Scottsbluff, NE, [5]University of Nebraska, Concord, NE (81)

Influence of Late Emerging Weeds on the Yield of Glyphosate-Resistant Soybean. Nader Soltani*[1], Amit Jhala[2], Robert E. Nurse[3], Peter H Sikkema[1]; [1]University of Guelph, Ridgetown, ON, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]Agriculture Canada, Harrow, ON (82)

†Soybean Yield as Affected by Planting Date and Seed Treatment. Kelsey Bergman*[1], Brent Heaton[2], Mark Bernards[1]; [1]Western Illinois University, Macomb, IL, [2]Western Illinois University, Industry, IL (83)

†Effect of Soil-Applied Sulfentrazone and Flumioxazin on Soybean Seedling Disease Severity Under Field Conditions. Nicholas J. Arneson*, Loren J. Giesler, Rodrigo Werle; University of Nebraska-Lincoln, Lincoln, NE (84)

†The Interactive Effects of Soybean Sensitivity to PPO-Inhibiting Hebicides, Seed Treatment, and Seeding Rate on Yield and Disease. Rhett Stolte*[1], Ahmad M. Fakhoury[2], Jason P. Bond[2], Karla Gage[1]; [1]Southern Illinois University, Carbondale, IL, [2]Plant Pathologist, Carbondale, IL (85)

†Impact of Soil-Applied PPO and PSII Herbicides on Early Season Soybean and Palmer Amaranth Development. Nikola Arsenijevic*[1], Matheus de-Avellar[1], Liberty Butts[2], Rodrigo Werle[3]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Nebraska Lincoln, North Platte, NE, [3]University of Nebraska-Lincoln, Lincoln, NE (86)

†What's in Your Bird Feeder? Screening Commercial Bird Feed Mixes for Viable Weed Seed Contaminants. Eric Oseland*[1], Mandy Bish[2], Kevin W Bradley[2]; [1]University of Missouri, Columbia, IL, [2]University of Missouri, Columbia, MO (87)

Characterization of a Palmer Amaranth Population with Reduced Sensitivity to PPO-Inhibiting Herbicides and Lacking Known Target Site Mutations. Hailey B. Holcomb*[1], Haozhen Nie[1], Julie M. Young[2], Bryan G. Young[1]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, WEST LAFAYETTE, IN (88)

†Confirmation of a Common Waterhemp Biotype Resistant to Protoporphyrinogen Oxidase (PPO) Inhibitors in Nebraska. Trey Stephens*, Debalin Sarangi, Amit J. Jhala; University of Nebraska-Lincoln, Lincoln, NE (89)

Halauxifen-methyl, 2,4-D, Dicamba, and Glyphosate Tank-Mixtures Efficacy on Broadleaf Weeds. Marcelo Zimmer*[1], Bryan G. Young[1], Bill Johnson[2]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, W Lafayette, IN (90)

Fierce MTZ: A New Preemergence Soybean Herbicide. Eric J. Ott*[1], John A. Pawlak[2], Dawn E. Refsell[3], Ron E. Estes[4], Jon R. Kohrt[5], Lowell D. Sandell[6], Trevor D. Israel[7]; [1]Valent USA LLC, Greenfield, IN, [2]Valent USA LLC, Lansing, MI, [3]Valent USA LLC, Lathrop, MO, [4]Valent USA LLC, Tolono, IL, [5]Valent USA LLC, West Des Moines, IA, [6]Valent USA LLC, Lincoln, NE, [7]Valent USA LLC, Souix Falls, SD (91)

Efficacy of Tavium™ Herbicide Plus VaporGrip® Technology in Dicamba-Tolerant Soybeans and Cotton. Scott A. Payne*[1], Brett Miller[2], James C. Holloway[3], Erin M. Hitchner[4], Donald J. Porter[5]; [1]Syngenta, Slater, IA, [2]Syngenta, Minnetonka, MN, [3]Syngenta, Jackson, TN, [4]Syngenta, Elmer, NJ, [5]Syngenta, Greensboro, NC (92)

Control of Volunteer Glyphosate-Tolerant Alfalfa in No-Till Roundup Ready Xtend Soybean. Lisa M. Behnken*[1], Fritz Breitenbach[2], Annette Kyllo[1]; [1]University of Minnesota Extension, Rochester, MN, [2]Univ of Minn Extension, Rochester, MN (93)

Comparisons of Weed Management Intensity Levels Utilizing Roundup Ready Xtend and LibertyLink Soybean. Damian Franzenburg*[1], M D K Owen[2], James Lee[2], Iththiphonh Macvilay[2]; [1]Iowa State Univesity, Ames, IA, [2]Iowa State University, Ames, IA (94)

†Efficacy of Glufosinate and Dicamba Tank-Mixtures on Common Lambsquarters, Palmer Amaranth, Corn, and Grain Sorghum. Milos Zaric*[1], Karla A. Romero[2], Jeffrey Golus[1], Greg R Kruger[3]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Zamorano, Zamorano, Honduras, [3]University of Nebraska, North Platte, NE (95)

Weed Control with Selected Dicamba Treatments in Northeast Nebraska. Jon E Scott*[1], Stevan Z. Knezevic[2]; [1]University of Nebraska, Concord, NE, [2]University of Nebraska-Lincoln, Concord, NE (96)

†Scheduled Herbicide Applications and Micro-Rates for Weed Management in Dicamba-Resistant Soybean. Nathan Hilleson*[1], Brent Heaton[2], Mark Bernards[1]; [1]Western Illinois University, Macomb, IL, [2]Western Illinois University, Industry, IL (97)

†Evaluation of Glyphosate-Resistant Palmer Amaranth Control with Two-Pass Programs in Dicamba- and Glufosinate-Tolerant Soybean Systems. Colton P. Carmody*[1], Karla Gage[2], Ron Krausz[3]; [1]Graduate Student, Carbondale, IL, [2]Southern Illinois University, Carbondale, IL, [3]Southern Illinois University, Belleville, IL (98)

†Strategies for Control of Palmer Amaranth that Survived a POST Contact Herbicide. Jesse A. Haarmann*, Bryan G. Young, William G. Johnson; Purdue University, West Lafayette, IN (99)

†Evaluation of "Recovery" Treatments for Dicamba-Injured Soybean. Shea Farrell*, Mandy Bish, Kevin W Bradley; University of Missouri, Columbia, MO (100)

†Utilizing Geospatial Technology to Assess Off-target Dicamba Injury and Yield Loss in Missouri Soybean Fields. Brian R. Dintelmann*, Shea Farrell, Kent Shannon, Mandy Bish, Kevin W Bradley; University of Missouri, Columbia, MO (101)

†Impact of Simulated Dicamba Drift on Sensitive Soybean. Jerri Lynn Henry*, Reid Smeda; University of Missouri, Columbia, MO (102)

†Glyphosate-Resistant Soybean Response to Sequential Applications of Dicamba and other Postemergence Herbicides. Nicholas C. Hayden*, William G. Johnson, Bryan G. Young; Purdue University, West Lafayette, IN (103)

Growth and Development of Irrigated Glyphosate-Tolerant Soybeans as Influenced by Micro-Rates of Clarity. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (104)

Yield of Irrigated Glyphosate-Tolerant Soybeans as Influenced by Micro-Rates of Clarity. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (105)

Yield of Dryland Glyphosate-Tolerant, Glufosinate-Tolerant, and Conventional Soybeans as Influenced by Micro-Rates of Clarity. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (106)

Growth and Development of Dryland Glyphosate-Tolerant, Glufosinate-Tolerant, and Conventional Soybeans as Influenced by Micro-Rates of Clarity. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (107)

Growth and Development of Irrigated Glyphosate-Tolerant Soybeans as Influenced by Micro-Rates of Engenia. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (108)

Yield of Irrigated Glyphosate-Tolerant Soybeans as Influenced by Micro-Rates of Engenia. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (109)

Growth and Development of Dryland Glyphosate-Tolerant, Glufosinate-Tolerant, and Conventional Soybeans as Influenced by Micro-Rates of Engenia. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (110)

Yield of Dryland Glyphosate-Tolerant, Glufosinate-Tolerant, and Conventional Soybeans as Influenced by Micro-Rates of Engenia. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (111)

Growth and Development of Irrigated Glyphosate-Tolerant Soybeans as Influenced by Micro-Rates of XtendiMax. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (112)

Yield of Irrigated Glyphosate-Tolerant Soybeans as Influenced by Micro-Rates of XtendiMax. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (113)

Growth and Development of Dryland Glyphosate-Tolerant, Glufosinate-Tolerant, and Conventional Soybeans as Influenced by Micro-Rates of XtendiMax. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (114)

Yield of Dryland Glyphosate-Tolerant, Glufosinate-Tolerant, and Conventional Soybeans as Influenced by Micro-Rates of XtendiMax. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (115)

Agronomic and Specialty Crops (All other agronomic and horticultural crops)

Potential Yield Loss Due to Weeds in Dry Beans in Canada and the United States. Nader Soltani*[1], J. Anita Dille[2], Peter H Sikkema[1]; [1]University of Guelph, Ridgetown, ON, [2]Kansas State University, Manhattan, KS (58)

†Dry Bean, Sugarbeet, Alfalfa, and Cucumber Response to Bicyclopyrone Residues. Daniel Wilkinson*[1], Christy L. Sprague[2]; [1], DeWitt, MI, [2]Michigan State University, East Lansing, MI (59)

Performance of Field Pea Herbicides in Western Nebraska. Samuel T. Koeshall*[1], Rodrigo Werle[1], Cody Creech[2]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Scottsbluff, NE (60)

Safflower Variety Susceptibility to Sulfentrazone Injury. Clair L. Keene*[1], Caleb Dalley[2]; [1]North Dakota State University, Williston, ND, [2]North Dakota State University, Hettinger, ND (61)

†Response of White and Yellow Popcorn Hybrids to Glyphosate, Enlist DUO, or XtendiMax. Ethann R. Barnes*[1], Nevin C. Lawrence[2], Stevan Z. Knezevic[3], Amit Jhala[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Scottsbluff, NE, [3]University of Nebraska-Lincoln, Concord, NE (62)

Grain Sorghum Response to POST Pyrasulfotole and Bromoxynil Previously Treated with PRE Herbicides Containing Mesotrione. Seth Menzer, Curtis R Thompson*, Mithila Jugulam; Kansas State University, Manhattan, KS (63)

†Growth and Reproductive Response of Missouri Grapes to Dicamba. Sarah E. Dixon*[1], Reid Smeda[2]; [1]Graduate Research Assistant, Columbia, MO, [2]University of Missouri, Columbia, MO (64)

Sensitivity of Irrigated Grapes to Micro-Rates of Clarity, Engenia, and XtendiMax. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (65)

Sensitivity of Irrigated Tomato to Micro-Rates of Clarity, Engenia, and XtendiMax. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (66)

†Evaluation of a New Herbicide, Switchblade, for Broadleaf Weed Control. Matthew C. Fleetwood*[1], Jeff Marvin[2], Dale Sanson[2], Xi Xiong[1]; [1]University of Missouri, Columbia, MO, [2]PBI Gordon, Kansas City, KS (67)

Equipment and Application Methods

†Visualization of the Penetration and Uptake of Multiple Adjuvant Systems Using Confocal Microscopy. Savana M. Lipps*[1], Gregory K. Dahl[2], Joe V. Gednalske[2], Raymond L. Pigati[3]; [1]University of Wisconsin-Madison, Madison, WI, [2]Winfield United, River Falls, WI, [3]WinField United, Shoreview, MN (49)

†Impact of Nozzle Selection on POST Applications of HPPD-Inhibiting Herbicides. Vinicius Velho*[1], Jeffrey Golus[1], Kasey Schroeder[1], Greg R Kruger[2]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Nebraska, North Platte, NE (50)

†Impact of Nozzle Selection and Tank-mixture on Weed Efficacy. Debora O. Latorre*[1], Dan Reynolds[2], Bryan G. Young[3], Jason Norsworthy[4], Stanley Culpepper[5], Kevin Bradley[6], Ryan Rector[7], Wayne Keeling[8], David Nicolai[9], Mandy Bish[6], Greg R Kruger[10]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]Mississippi State University, Starkville, MS, [3]Purdue University, West Lafayette, IN, [4]University of Arkansas, Fayetteville, AR, [5]University of Georgia, Titon, GA, [6]University of Missouri, Columbia, MO, [7]Monsanto Company, St. Charles, MO, [8]Texas A&M, Lubbock, TX, [9]University of Minnesota, Farmington, MN, [10]University of Nebraska, North Platte, NE (51)

†Effects of Solution Viscosity on Herbicide Efficacy. Gabrielle C. Macedo*[1], Glen Obear[2], Frank Sexton[3], Jeffrey Golus[1], Kasey Schroeder[1], Greg R Kruger[4]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]Exacto, Inc., Sharon, WI, [4]University of Nebraska, North Platte, NE (52)

†Impact of Droplet Size on POST Applications of HPPD-Inhibiting Herbicides. Barbara Vukoja*[1], Jeffrey Golus[1], Kasey Schroeder[1], Greg R Kruger[2]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Nebraska, North Platte, NE (53)

†Impact of Droplet Size and Weed Size on HPPD-Inhibiting Herbicide Efficacy. Thiago H. Vitti*[1], Jeffrey Golus[1], Kasey Schroeder[1], Greg R Kruger[2]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Nebraska, North Platte, NE (54)

†Wheat Stubble Height and Nozzle Type Influences Spray Penetration of a Dicamba and Glyphosate Tank Mixture. Luana M. Simao*[1], Greg R Kruger[2], Cody Creech[1]; [1]University of Nebraska-Lincoln, Scottsbluff, NE, [2]University of Nebraska, North Platte, NE (55)

†Influence of Agitation Systems and Sitting Time on Droplet Size with XtendiMax, Roundup Xtend, Clarity and Roundup PowerMax. Andre O. Rodrigues*[1], Ulisses R. Antuniassi[2], Cody Creech[3], Bradley K. Fritz[4], Greg R Kruger[5]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]UNESP, Botucatu, Brazil, [3]University of Nebraska-Lincoln, Scottsbluff, NE, [4]ARS-USDA, College Station, TX, [5]University of Nebraska, North Platte, NE (56)

Effectiveness of Hyperspectral Imaging Technology in Detecting Herbicide Injury. Julie M. Young*[1], Haozhen Nie[2], William G. Johnson[2], Jian Jin[1], Bryan G. Young[2]; [1]Purdue University, WEST LAFAYETTE, IN, [2]Purdue University, West Lafayette, IN (57)

Extension

†Horseweed Control: Fall versus Spring Herbicide Application Timing. Josh Wehrbein*[1], Lowell Sandell[2], Christopher Proctor[1]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]Valent, Lincoln, NE (44)

Digital Books for Weed Science - Now Cooking with Weeds. Bruce Ackley*, Alyssa Lamb; The Ohio State University, Columbus, OH (45)

Demonstrating Herbicide Programs in Current and Future Soybean Technologies. Joe Ikley*[1], Bill Johnson[2], Bryan G. Young[1]; [1]Purdue University, West Lafayette, IN, [2]Purdue University, W Lafayette, IN (46)

An Overview of Herbicide-Resistant Weeds in Kansas. Vipan Kumar*[1], Prashant Jha[2], Phillip Stahlman[1], Mithila Jugulam[3], Randall S Currie[4], J. Anita Dille[3], Dallas E. Peterson[3], Curtis R Thompson[3], Douglas E Shoup[5]; [1]Kansas State University, Hays, KS,

[2]Montana State University, Huntley, MT, [3]Kansas State University, Manhattan, KS, [4]Kansas State University, Garden City, KS, [5]Kansas State University, Chanute, KS (47)

2017 EPA Tour of Western Kansas. Dallas E. Peterson*[1], Phillip Stahlman[2], Curtis R Thompson[1], J. Anita Dille[1], Mithila Jugulam[1], Randall S Currie[3], Michael Barrett[4], Jill Schroeder[5], Lee Van Wychen[6]; [1]Kansas State University, Manhattan, KS, [2]Kansas State University, Hays, KS, [3]Kansas State University, Garden City, KS, [4]University of Kentucky, Lexington, KY, [5]USDA Office of Pest Management Policy, Washington, DC, [6]WSSA, Alexandria, VA (48)

Herbicide Physiology

†Evaluation of ACCase-Inhibitor and Growth Regulator Herbicide Tank-Mixtures. Bonheur Ndaysihimiye*[1], Jeffrey Golus[2], Kasey Schroeder[2], Bruno Canella Vieira[3], Andre O. Rodrigues[2], Greg R Kruger[4]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, North Platte, NE, [3]University of Nebraska, Lincoln, NE, [4]University of Nebraska, North Platte, NE (33)

†Effects of Glyphosate, Glufosinate, and Dicamba Tank-Mixtures. Rodger Farr*[1], Jeffrey Golus[1], Greg R Kruger[2]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Nebraska, North Platte, NE (34)

†Interaction of HPPD-Inhibiting Herbicides with Glyphosate, Glufosinate, 2,4-D and Dicamba. Vera Vukovic*[1], Jeffrey Golus[1], Kasey Schroeder[1], Greg R Kruger[2]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Nebraska, North Platte, NE (35)

†Resistance to Carfentrazone-ethyl in Tall Waterhemp. Olivia A. Obenland*[1], Rong Ma[2], Sarah O'Brien[3], Anatoli V. Lygin[1], Dean E Riechers[4]; [1]University of Illinois at Urbana-Champaign, Urbana, IL, [2]University of Illinois, Urbana, IL, [3]University of Illinois at Urbana-Champaign, Urban, IL, [4]Univ of Illinois Crop Science, Urbana, IL (36)

†Tall Waterhemp Resistance to PPO-Inhibiting Herbicides: Does *s*-Metolachlor Reduce Selection Pressure, Decrease Overall Survivorship, or Both? Brent C. Mansfield*[1], Haozhen Nie[1], Julie M Young[2], Bryan G. Young[1]; [1]Purdue University, West Lafayette, IN, [2], Brookston, IN (37)

Rapid Metabolism Contributes to Atrazine Resistance in Common Waterhemp from Nebraska. Amarnath R. Vennapusa*[1], Felipe Faleco[2], Bruno Vieira[3], Spencer Samuelson[4], Greg R Kruger[5], Rodrigo Werle[6], Mithila Jugulam[1]; [1]Kansas State University, Manhattan, KS, [2]University of Nebraska Lincoln, North Platte, NE, [3]University of Nebraska, Lincoln, North Platte, NE, [4]University of Nebraska, Lincoln, NE, [5]University of Nebraska, North Platte, NE, [6]University of Nebraska-Lincoln, Lincoln, NE (38)

†Rapid Metabolism Increases Resistance to 2,4-D in Common Waterhemp Under High Temperature. Chandrima Shyam*[1], Junjun Ou[2], Greg R Kruger[3], Mithila Jugulam[1]; [1]Kansas State University, Manhattan, KS, [2]Kansas State Univ., Dep of Agronomy, Manhattan, KS, [3]University of Nebraska, North Platte, NE (39)

Qualification of EPSPS Gene Duplication for Glyphosate Resistance in Palmer Amaranth. Chenxi Wu*[1], Zoee Perrine[2], Brian D. Eads[2], Geliang Wang[2], R. Douglas Sammons[3]; [1]Monsanto Company, St Louis, MO, [2]Monsanto, St Louis, MO, [3]Monsanto, Chesterfield, MO (40)

†Molecular Screening of PPO and Glyphosate Resistance in Palmer Amaranth Populations from Southwest Nebraska. Gustavo Vieira*[1], Maxwel C. Oliveira[2], Darci Giacomini[3], Nikola Arsenijevic[1], Patrick Tranel[3], Rodrigo Werle[4]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Nebraska-Lincoln, Concord, NE, [3]University of Illinois, Urbana, IL, [4]University of Nebraska-Lincoln, Lincoln, NE (41)

Adapting a Media-Based Root Inhibition Assay to Investigate Differences in Auxin Herbicide Response in Horseweed. Cara L. McCauley*, Bryan G. Young; Purdue University, West Lafayette, IN (42)

Cytochrome P450-Mediated Metabolism of Mesotrione and Tembotrione in HPPD-Inhibitor-Tolerant Sorghum. Balaji Aravindhan Pandian*, Amaranatha R. Vennapusa, Curtis R Thompson, Vara Prasad PV, Mithila Jugulam; Kansas State University, Manhattan, KS (43)

Invasive Weeds, Rangeland, Pasture, and Vegetation Management

PGR Options for Roadside Tall Fescue Management. Joe Omielan*, Michael Barrett; University of Kentucky, Lexington, KY (1)

Cottonwood, Buckbrush and Yellow Bluestem Control in Nebraska Pasture. Stevan Z. Knezevic*[1], Jon E Scott[2]; [1]University of Nebraska-Lincoln, Concord, NE, [2]University of Nebraska, Concord, NE (2)

†Common Milkweed Establishment in Existing Perennial Sod. Sydney Lizotte-Hall*, Bob Hartzler; Iowa State University, Ames, IA (3)

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Survey of Cover Crop Management in Nebraska. Liberty Butts*[1], Rodrigo Werle[2]; [1]University of Nebraska Lincoln, North Platte, NE, [2]University of Nebraska-Lincoln, Lincoln, NE (7)

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†Critical Time for Weed Removal in Corn as Influenced by PRE Herbicides. Ayse Nur Ulusoy*[1], O. Adewale Osipitan[2], Jon E Scott[3], Stevan Z. Knezevic[2]; [1]University of Nebraska-Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Concord, NE, [3]University of Nebraska, Concord, NE (17)

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†Breaking Seed Dormancy in Palmer Amaranth. Samuel N. Ramirez*, Rhett Stolte, Karla Gage; Southern Illinois University, Carbondale, IL (20)

†Methods of Breaking Seed Dormancy in Common Waterhemp. Dustin W. Bierbaum*, Rhett Stolte, Karla Gage; Southern Illinois University, Carbondale, IL (21)

†Density-Dependent Johnsongrass Seed Production Under Different Cropping Systems. Don Treptow*[1], Rodrigo Werle[2], Amit J. Jhala[2], Melinda Yerka[2], Brigitte Tenhumberg[1], John Lindquist[3]; [1]University of Nebraska - Lincoln, Lincoln, NE, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]University of Nebraska, Lincoln, NE (22)

†Using Seed Rain to Assess Feasibility of At-Harvest Seed Destruction for Three Troublesome Weed Species in Missouri Soybean. Alyssa Hultgren*[1], Mandy Bish[2], Sarah Lancaster[3], Kevin W Bradley[2]; [1]University of Missouri and Missouri State University, Springfield, MO, [2]University of Missouri, Columbia, MO, [3]Missouri State University, Springfield, MO (23)

†Effect of Degree of Water Stress on the Growth and Fecundity of Palmer Amaranth. Parminder Chahal*, Suat Irmak, Amit Jhala; University of Nebraska-Lincoln, Lincoln, NE (24)

†Waterhemp Seed Production and Seed Viability as Affected by Sublethal Dicamba Dose. Allyson Rumler*[1], Brent Heaton[2], Mark Bernards[1]; [1]Western Illinois University, Macomb, IL, [2]Western Illinois University, Industry, IL (25)

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†Investigation of Herbicide-Resistant Italian Ryegrass in Western Kentucky. Zachary K. Perry*[1], Travis Legleiter[2]; [1]University of Kentucky, Lexington, KY, [2]University of Kentucky, Princeton, KY (28)

†Sorting through Multiple Mechanisms of PPO-Inhibitor Resistance in Palmer Amaranth and Waterhemp. Kathryn Lillie*[1], Darci Giacomini[1], James R Martin[2], J D Green[3], Patrick Tranel[1]; [1]University of Illinois, Urbana, IL, [2]University of Kentucky, Princeton, KY, [3]University of Kentucky, Lexington, KY (29)

†Inheritance of Mesotrione Resistance in a Waterhemp Population from Nebraska. Maxwel C. Oliveira*[1], Todd A. Gaines[2], Stevan Z. Knezevic[1]; [1]University of Nebraska-Lincoln, Concord, NE, [2]Colorado State University, Fort Collins, CO (30)

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†Artificial Hybridization Between *Amaranthus tuberculatus* and *Amaranthus albus*. Brent Murphy*[1], Laura A. Chatham[2], Patrick Tranel[1]; [1]University of Illinois, Urbana, IL, [2]University of Illinois, Champaign, IL (32)

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Abstracts

PGR OPTIONS FOR ROADSIDE TALL FESCUE MANAGEMENT. Joe Omielan*, Michael Barrett; University of Kentucky, Lexington, KY (1)

Tall fescue is a widely adapted species and is a common roadside and other unimproved turf cool season grass. Frequent mowing is the most common management regime for departments of transportation. Plant Growth Regulators (PGRs) are potential tools to reduce turf growth and aid in keeping our roadways safe for travelers. This trial was established to evaluate some PGR options for roadside management. A trial was established in 2017 at Spindletop Research Farm in Lexington, KY arranged as a complete block design with 21 PGR treatments and three replications. Plots were 2 m by 6 m with running unsprayed checks between each of the plots. The treatments were five PGRs applied before the first mowing and one to two weeks after each of the three mowings plus control. Herbicides tested were mefluidide, imazapic, aminopyralid + metsulfuron-methyl, prohexadione calcium, and aminocyclopyrachlor + clorsulfuron. Applications were at 234 L ha-1 and included a non-ionic surfactant at 0.25% v v-1. Application dates were 4/26/2017, 6/1/2017, 8/8/2017, and 9/6/2017. Tall fescue color was assessed by comparison to the running check strips. The color rating ranges from 0 (dead) to 9 (full green). The color of the check strips was set at eight. Seedhead suppression was assessed before the first mowing. Canopy heights were measured. Data were analyzed using ARM software and treatment means were compared using Fisher's LSD at p = 0.05. The effects of the PGR treatments were variable however, in general, many of the treatments reduced grass height along with turf color but color recovered and turf was deeper green for a while afterwards.

COTTONWOOD, BUCKBRUSH AND YELLOW BLUESTEM CONTROL IN NEBRASKA PASTURE. Stevan Z. Knezevic*1, Jon E Scott2; 1University of Nebraska-Lincoln, Concord, NE, 2University of Nebraska, Concord, NE (2)

There is about one million hectares of rangeland and pasture in Nebraska, which spans from eastern, north-central and western part of the state. Yellow bluestem (warm season grass) and buckbrush (shrub) are perennial weeds found in south-eastern and north-eastern parts of the state, respectively. Cottonwood and its seedlings are commonly found in sub-irrigated meadows throughout the state. Our objective was to test various herbicides for control of these three species during springs of 2016 and 2017. Yellow bluestem was sprayed at flowering time (mid-July) while buckbrush and cottonwood at one meter of new growth (late-May to early-June). Aminocyclopyrachlor applied at 310 g ai ha-1 provided the best and the longest lasting control (over 12 months) of buckbrush. Only one season (five months) suppression (70-80%) of buckbrush was achieved with 2,4-D at 3200 g ai ha-1; metsulfuron+chlorsulfuron at 22 g ai ha-1 or picloram+2,4-D at 1420 g ai ha-1. Cottonwood was controlled the best (>90%) with picloram + 2,4-D at 1420 g ai ha-1; Metsulfuron + 2,4-D + dicamba (42 g ai ha-1 + 2170 g ai ha-1) or picloram at 840 g ai ha-1. The longest lasting control (over 12 months) of yellow bluestem was achieved with imazapyr at 840 g ai ha-1 and 1400 g ai ha-1. Glyphosate at 4620 g ai ha-1 and 7700 g ai ha-1 provided yellow bluestem suppression for the whole season (five months), however there was a regrowth of bluestem in the following year. Due to non-selective nature of imazapyr and glyphosate, there was over 80% damage of native grass and other useful species. Our results suggest that there are excellent herbicides available for the control of buckbrush and cottonwood. Yellow bluestems are much harder control with herbicides alone, however herbicides might be useful tool in an integrated management plan, thus additional studies are needed to confirm such hypothesis.

COMMON MILKWEED ESTABLISHMENT IN EXISTING PERENNIAL SOD. Sydney Lizotte-Hall*, Bob Hartzler; Iowa State University, Ames, IA (3)

Lack of resources in the summer reproductive range is believed to be a contributing factor in the decline of the monarch butterfly (Danaus plexippus). Most farms have small areas of land not utilized for crop production and recreation. The most common species used as cover in these areas is smooth bromegrass (Bromus inermis). The purpose of this study is to investigate a simple method for establishing monarch host plants into existing sod landscapes. We hypothesize that suppression of smooth bromegrass will reduce interspecific competition, allowing for increased establishment of common milkweed (Asclepias syriaca) and three forbs, wild bergamot (Monarda fistulosa), golden alexanders (Zizia aurea), and New England aster (Symphyotrichum novae-angliae). Common milkweed serves as both a nectar source for adults and food source for developing larvae, whereas the three forbs provide floral resources for adult monarchs. Common milkweed seed was hand collected from Story County, Iowa in September and sent to Iowa State University Seed Lab for a viability test. The forb seed was purchased from a local producer of native plants. Field experiments were initiated in 2015 and 2016. A factorial arrangement of treatments was used to evaluate contributions of mowing and low rates of glyphosate in aiding establishment of the four species in established sods. Randomly assigned plots were mowed in August to a height of approximately 20 cm. Two rates of glyphosate (0.25 kg ha-1 and 0.50 kg ha-1) plus a control were applied to subplots in September using a backpack sprayer. Seeds were mixed with wood shavings to ensure even distribution when hand seeding within a 1.5 m2 quadrat in December. Three seeding treatments were used for common milkweed (100 plants m-2, 100 plants m-2 + mid-June mowing, and 2000 plants m-2), whereas a single seeding rate was used for the other forbs. Seedling counts and visual ratings of weed presence were conducted weekly from June through August. Biomass samples were collected using a 0.09 m-2 quadrat from the center of each sub-subplot. Samples were separated into common milkweed, cool-season grass, and weeds. Samples were oven-dried at 140 C for one week. Only results of the experiment initiated in 2015 will be discussed. Biomass of common milkweed and weeds were affected by treatments, but not the cool-season grasses. Common milkweed counts declined dramatically by the end of Year 2. The main effect for herbicide was significant for presence/absence of milkweed at the end of Year 1 ($p = 0.0049$), but not at the end of Year 2 ($p = 0.1677$). Most milkweed present during Year 2 appeared to emerge from seed rather than rootstocks. Glyphosate treatment increased the presence of the three forbs at the end of Year 2. The interaction between mowing and glyphosate was significant with golden alexanders, with greater establishment with a combination of mowing and glyphosate than either factor alone. Our results indicate suppression of a perennial sod with sub-lethal rates of glyphosate can increase recruitment of seedlings, but there is still a low probability of permanently establishing common milkweed and other forbs. More intense disturbance may increase establishment, but is likely to increase invasion of the area by weedy species.

FIELD PERFORMANCE OF A NOVEL 2,4-D TOLERANT RED CLOVER. Lucas P. Araujo*, Michael Barrett, Gene Olson, Linda D. Williams; University of Kentucky, Lexington, KY (4)

Incorporation of a legume, such as red clover (Trifolium pratense), into grass-based pasture systems, offers many benefits. Available red clover lines are highly susceptible to herbicides, in particular, 2,4-D (2,4-dichlorophenoxyacetic acid), which has been widely used for broadleaf weed management in pastures. A novel red clover line, UK2014, was developed at the University of Kentucky through conventional breeding and expresses higher tolerance to 2,4-D than Kenland, a common variety used by Kentucky's forage producers. Adopting this new tolerant line would broaden weed management options in a legume-grass mixed pasture. The main objective of this study was to assess the field performance of UK2014, in terms of yield and 2,4-D tolerance level, compared to Kenland in Kentucky's environment. To accomplish this, both UK2014 and Kenland were seeded in April of 2016 and 2,4-D (both the 1.12 and 2.24 kg ha-1 rates) was applied either early (June 2016), mid (August 2016) or late (October 2016) season. Each plot received only one 2,4-D treatment and treated plots were compared to those that were not treated with 2,4-D. Visual herbicide injury was evaluated one week after spraying and one week after harvest. The red clover was harvested approximately one week after the 2,4-D applications were made. Both individual harvest and total season yield (dry matter ton ha-1) were determined. The experiment was repeated in 2017 in a new site next to the 2016 study. The 2017 study was seeded in May of 2017 and received the same treatments as in 2016, in early (July 2017), mid (August) and late (November 2017) seasons. Data were subjected to analysis of variance and means were separated using Fisher's Protected LSD at $\alpha = 0.05$. In the 2016 study, visual injury one week after 2,4-D treatment to UK2014 was less than that of Kenland, especially at the 2.24 kg ha-1 2,4-D rate. Similarly, in plots treated earlier with 2.24 kg ha-1 2,4-D, visual estimates of regrowth one week after harvest were higher for UK2014 than Kenland. However, there were no differences in yield between UK2014 and Kenland at individual harvests or in the season total. Similar trends were observed in the 2017 study. While this indicated that the performance of UK2014 is equal to Kenland in terms of yield, it also indicated that the 2,4-D injury to Kenland was not enough to reduce its yield during the analyzed periods. Future research will follow the effects of 2,4-D on the persistence of these two lines in both monoculture and mixed species pastures.

WILD PARSNIP CONTROL WITH HERBICIDES AND MOWING. Kenneth Tryggestad, Mark Bernards*; Western Illinois University, Macomb, IL (5)

Wild parsnip (Pastinaca sativa) is a biennial weed that invades roadsides and natural areas. Contact with sap from the leaves or stems in combination with sunlight will lead to blistering and discoloration of skin. It is our observation that wild parsnip is becoming more prevalent in Illinois. Our objective was to evaluate herbicides and mechanical controls for wild parsnip control over 12 months. Western Illinois University's Rodney and Bertha Fink Environmental Field Studies and Laboratory located in Macomb, IL, is designated as a natural area, but is mowed each year in early August. We identified two areas with relatively abundant and uniform wild parsnip populations and established a randomized complete block design study with three replications in May 2016. Plot size was 3 x 12 m (rep 1) or 3 x 15 m (reps 2 and 3). Herbicide treatments were applied in May prior to wild parsnip bolting using a CO2 backpack sprayer and a four nozzle boom calibrated to deliver 140 L ha-1. Treatments included 1) metsulfuron-methyl (15.4 g ai ha-1) + MSO (1% v v-1); 2) 2,4-D lo-vol ester (2130 g ae ha-1) + COC (1% v v-1); 3) dicamba (280 g ae ha-1) + 2,4-D (2130 g ha-1); 4) metsulfuron methyl (15.4 g ai ha-1) + aminocylopyrachlor (48.3 g ai ha-1) + MSO (1% v v-1); 5) aminocyclopyrachlor (48.3 g ai ha-1) + MSO (1% v v-1), 6) mowing and 7) untreated. Wild parsnip was mowed (treatment 6) in June, prior to the appearance of flowers. Visual control estimates were made in July 2016 and again in July 2017 on a scale of 0=no control to 100=complete control. Data were subjected to ANOVA and means were separated using LSD. Control of wild parsnip six weeks after herbicide application (WAT) was 90% for treatments 1-4. Wild parsnip control was 70% for aminocyclopyrachlor (treatment 5) and mowing when compared to the untreated at six WAT. When the study was evaluated in July 2017 plots that had been mowed in 2016 had greater densities of wild parsnip than the untreated plots. Consequently, treatments were evaluated in comparison to the mowed plots. Fourteen months after treatment, herbicide treated plots averaged 90% reduction in wild parsnip density and growth. There were no differences among herbicide treatments. Surprisingly, wild parsnip density was reduced 85% in the "untreated" when compared to mowed plots. There was a high diversity of forbs in the untreated plots when compared to herbicide treated and mowed plots. It is our conclusion that mowing removes vegetation that suppresses wild parsnip and favors increased infestations.

INTEGRATION OF VARYING PLANT POPULATIONS AND DICAMBA RATES FOR PALMER AMARANTH CONTROL IN IRRIGATED CORN. Ivan Cuvaca*1, Randall S Currie2, Mithila Jugulam1; 1Kansas State University, Manhattan, KS, 2Kansas State University, Garden City, KS (6)

Dicamba is considered an effective alternative to glyphosate; however, its susceptibility to drift even with the availability of formulations developed to reduce off-target movement is a major concern. Therefore, use of reduced rates of dicamba has been proposed. This research investigated the effect of integration of varying corn (Zea mays) populations and dicamba rates on Palmer amaranth (Amaranthus palmeri) control in an irrigated environment near Garden City, KS using a randomized complete block design with a split-plot arrangement and five (2016) or four (2017) replicates. The hypothesis was that integration of reduced dicamba rates in conjunction with greater corn population densities may provide acceptable Palmer amaranth control while maintaining yield. Main plots consisted of corn planted at five population densities ranging from ~50,000 to 100,000 plants ha-1 and sub-plot consisted of six dicamba rates (560, 420, 280, 210, 140, and 70 g ae ha-1) applied as late-POST (~V6), a weedy-check, and a weed-free check. Palmer amaranth was broadcast-seeded uniformly in experimental units at ~535 g ha-1 prior to corn planting. Increase in corn population density from 74,131 to 98,842 plants ha-1 with or without highest dicamba rate increased grain yield ~5 and 9%, respectively. When reduced dicamba rates were applied, greater corn population density did not reduce Palmer amaranth density or height but reduced biomass. Differences in normalized vegetation index (NDVI; indicative of photosynthetic activity) were observed only in 2017 with 98,842 plants ha-1 corn having the greatest values (≥0.82). Although NDVI increased with increased corn population density, overall, weedy corn had the greatest value, suggesting that the high NDVI values were associated with the mixed corn-Palmer amaranth canopy. The results suggest that while there is an opportunity to maintain grain yield and reduce potential off target movement of dicamba with increased corn population and reduced dicamba rate, Palmer amaranth control may not be adequate unless additional tactics are integrated.

SURVEY OF COVER CROP MANAGEMENT IN NEBRASKA. Liberty Butts*1, Rodrigo Werle2; 1University of Nebraska Lincoln, North Platte, NE, 2University of Nebraska-Lincoln, Lincoln, NE (7)

Cover crops (CC) have increased in popularity across the United States. In an effort to evaluate current CC management strategies adopted in Nebraska, a survey was conducted during the 2017 Cover Crop Conference (2/14/2017), held at the Eastern Nebraska Research and Extension Center near Ithaca, NE. A total of 82 growers and agronomists, representing 28 counties (mainly from eastern Nebraska), completed the surveys. A total of 87% of total participants adopt cover crops as part of their cropping systems. A total of 149,334 hectares were represented in this survey, with 24,238 hectares planted to cover crops. CC seeding time and methods, species selection, termination and herbicide programs, impact on the production system, and challenges were the main data collected. The main method of establishing cover crops following soybeans and field corn were drilling and aerial seeding, respectively. Cereal rye appeared to be the most adopted cover crop species (either alone or in a mix). Over 95% of respondents utilize herbicides for CC termination in the spring. Moreover, of those 95%, 100% utilize glyphosate, with 65% utilizing a second mode of action in the tank-mixture. According to respondents, the top reported benefits of incorporating CC into a production system were reduced soil erosion and weed suppression. The biggest challenge reported by CC adopters was planting and establishing a decent stand before winter. According to the results of this survey, there are different management strategies, positive outcomes, and challenges that accompany CC adoption in Nebraska. These results will help producers, agronomists, and the University of Nebraska-Lincoln better guide CC adoption and research needs in the state.

COVER CROP UTILIZATION AFFECTS WEED DYNAMICS IN TOBACCO. Erin Haramoto*, Bob Pearce; University of Kentucky, Lexington, KY (8)

Growers face trade-offs in managing cover crops optimally, especially when one of their goals is weed suppression. Later terminated cover crops may reduce weed density in cash crops, as more residue suppresses weed emergence and stresses weeds that do emerge. However, crop establishment may suffer as well. Removing cover crop biomass for forage may provide additional revenue, but little weed-suppressing residue remains in the field. Four site-years of on-farm field trials were used to study the impacts of cover crop termination time (early and late, relative to tobacco planting) and residue removal on weed density and biomass in tobacco. All site-years utilized a cover crop mixture of legumes and cereal rye (and canola in one site year); a wheat cover crop was also used in three site-years. Sulfentrazone was applied to plots prior to planting with an unsprayed area left in each plot to examine the impact of the cover crop treatments in the absence of a soil residual herbicide. Tobacco was transplanted using a modified no-till transplanter that produced moderate soil disturbance in the crop rows utilizing row cleaners, a deep shank, and coulters. Weed density was measured mid-season, and weed biomass was collected at harvest. Weeds were sampled from the areas with and without sulfentrazone, and sampled separately in and between the tobacco rows. We expected lower weed density following the late termination, particularly between the crop rows where residue remained intact, with larger differences between residue treatments expected where the residual herbicide was not applied. Cover crop species (i.e. mixture or monoculture wheat) had little influence on mid-season weed density. In the unsprayed areas, there were typically fewer weeds following the late terminated cover crop, particularly compared to residue removal. This was observed in two of four site-years in the between row zone, and one site-year in the in-row zone. Across the sprayed subplots, the late termination time resulted in lower weed density in one of four site-years in both the between-row and in-row zones. This treatment also resulted in lower weed density in the in-row zone regardless of herbicide use in two additional site years. Lastly, poor tobacco establishment in the late termination treatment led to much higher weed density, particularly in-row, in one site-year. By harvest, there were relatively few differences in the weed biomass among the unsprayed plots. In one site-year, in-row weed biomass was much higher following residue removal compared to the early or late termination. Between crop rows at this site, however, only the late termination time was effective in reducing final weed biomass. Differences across the sprayed areas were inconsistent between site years. These impacts on weed density and biomass are complex, illustrating the complicated interplay between species composition, residue treatment, and use of soil residual herbicides, as well as site-specific conditions and weather.

EVALUATION OF HERBICIDE TREATMENTS FOR TERMINATION OF CEREAL RYE AND CANOLA AS WINTER COVER CROPS. Stephanie DeSimini*1, Bill Johnson2; 1Purdue University, West Lafayette, IN, 2Purdue University, W Lafayette, IN (9)

The utilization of cover crops has increased in recent years due to government cost shares promoting the benefits of cover crops. Reducing soil erosion and compaction, increasing soil health, supplying nitrogen, and suppression of winter annuals and early spring weed growth are among the most suggested benefits of cover crops. While cereal rye is one of the most commonly used cover crops in the Midwest, various rapeseed cultivars, including canola are recommended for similar benefits. Reports in 2015 suggested an increase of glyphosate-tolerant canola seed contamination in cover crop mixtures in Indiana. Controlling these volunteers is an area of concern for Indiana growers. The objective of this study was to determine the most effective herbicide or herbicide combination for terminating canola and cereal rye prior to planting of a cash crop. A field experiment was conducted in 2016 at the Throckmorton Purdue Agriculture Center to determine the most effective herbicide program for the termination of cereal rye and canola. Cover crops were planted on 9/21/2016, and herbicide treatments were applied the following spring, three weeks before summer cash crop planting (WBP). Cereal rye and canola visual control was determined 28 d after application. Dicamba or 2,4-D with glyphosate provided less than 40% control of glyphosate-tolerant canola 28 d after treatment (DAT). Treatments containing glyphosate + saflufenacil provided only 60% control with significant regrowth. Comparatively, treatments containing paraquat + saflufenacil + 2,4-D and paraquat + saflufenacil + metribuzin provided 90% or higher control at 28 DAT. One treatment of cereal rye was terminated at two timings, an early and late timing. The late termination provided less than 50% control. These results show that early termination is important to prevent cover crop weediness later in the growing season, and that effective termination of RoundUp Ready canola can be successful with proper herbicide selection.

CEREAL RYE COVER CROP SUPRESSES WINTER ANNUAL WEEDS. Samuel T. Koeshall*1, Charles Burr2, Humberto Blanco-Canqui1, Rodrigo Werle1; 1University of Nebraska-Lincoln, Lincoln, NE, 2University of Nebraska-Lincoln, North Platte, NE (10)

Cover crop (CC) integration is increasing in North American cropping systems. Cereal rye (Secale cereale L.) has become a popular CC species as it is winter hardy and easy to establish into standing crops or after corn and soybean harvest. Winter annual weeds have become prolific in no-till fields across North America. Some winter annual weeds have evolved resistance to herbicides commonly applied in the fall or early spring (e.g., glyphosate-resistant horseweed). Cereal rye cover crop has the ability to suppress winter annual weeds by competing for space, light, water, and/or nutrients. The objective of this study was to evaluate the impact of cereal rye CC planted after corn silage harvest on winter annual weed density and biomass in the spring. The study was established at the West Central Research and Extension Center in North Platte, NE (WCREC) and at a producer field 10 km east of North Platte. Treatments consisted of cereal rye CC and winter fallow (no CC) arranged in a randomized complete block design with three replications. Prior to cereal rye CC termination and winter annual herbicide burndown, four 0.25 m2 quadrats were randomly placed within each plot from both treatments, weed species within each quadrat were identified and counted, and clipped for biomass estimation (4/18/17). Henbit and horseweed were the predominant winter annual weed species at WCREC whereas shepherd's purse and pinnate tansymustard dominated the producer site. Winter annual weed density between sites did not differ, but it differed between treatments. Across sites, cereal rye CC reduced winter annual weed density by 91% when compared to winter fallow. Cereal rye CC reduced winter annual weed biomass by 91% at WCREC and 95% at producer relative to winter fallow. Thus, cereal rye CC can be an effective component of an integrated winter annual weed management program while providing other desired ecosystem services (e.g., erosion control, soil organic C accumulation, reduction in N leaching).

EVALUATING COVER CROPS AND HERBICIDES FOR HORSEWEED MANAGEMENT IN NO-TILL SOYBEAN. Dallas E. Peterson, Anita Dille, Kraig L. Roozeboom, Larry Rains*; Kansas State University, Manhattan, KS (11)

The adoption of reduced tillage practices and reliance on herbicides for weed control has led to an increase in herbicide-resistant horseweed (Conyza canadensis) populations. Cover crops may be an effective management tool to control horseweed and provide further benefits to a cropping system, such as improve soil health, slow erosion, and enhance nutrient availability. A field experiment was conducted in fall 2016 through soybean harvest in 2017 in Manhattan, KS. The objective was to determine the effectiveness of fall and spring-planted cover crops and fall and spring-applied herbicides, both with and without residual, on horseweed control in a soybean crop. The experiment was arranged in a randomized complete block design with nine treatments and four replications. Four treatments were established on 10/25/2016 with triticale or oat cover crops sown into wheat stubble at 112 kg ha^{-1} and two herbicide treatments were applied without residual, including 2,4-D (1135 g ae ha^{-1}) plus dicamba (71 g ha^{-1}) and with residual including dicamba (285 g ha^{-1}) plus chlorimuron (29 g ha^{-1}) and flumioxazin (85 g ha^{-1}). Three treatments were established on 3/10/2017 with triticale or oats sown at 112 kg ha^{-1} and 2,4-D (1135 g ae ha^{-1}) plus dicamba (71 g ha^{-1}) was applied. Two other treatments were a weed-free and weedy control. Prior to termination of cover crops, horseweed density and biomass and cover crop biomass were measured. Cover crops were terminated two weeks prior to soybean planting with glyphosate (756 g ai ha-1) plus saflufenacil (10.3 g ai ha^{-1}) plus 2,4-D LV4 (214 g ai ha-1). Glufosinate-tolerant soybean was planted 6/7/2017 with a row spacing of 38.1 cm and a seeding rate of 346,000 seeds ha^{-1} and was harvested 11/1/2017. Spring-applied dicamba plus 2,4-D, fall-applied dicamba plus chlorimuron and flumioxazin, and fall-planted triticale resulted in lowest horseweed densities, with a reduction of 98, 92, and 80%, respectively, compared to the weedy control of 49 plants m-2. Similarly, horseweed biomass was lowest in these treatments, resulting in 98, 86, and 84% reduction, respectively, to the control of 0.28 kg m-2. Cover crop biomass was greatest with fall-planted triticale compared to oat or spring sown cover crops. Yield was greatest with fall-applied dicamba plus flumioxazin and chlorimuron. Fall-planted triticale, fall-applied herbicide with residual, and spring-applied herbicide without residual equally reduced horseweed densities and biomass.

EFFECT OF COVER CROP AND ROW CROP CULTIVATION ON PALMER AMARANTH IN GRAIN SORGHUM. Peter P. Bergkamp*, Marshall M. Hay, Anita Dille, Dallas E. Peterson; Kansas State University, Manhattan, KS (12)

Palmer amaranth is an invasive weed that has developed an extensive population in Kansas. It has evolved resistance to multiple herbicide modes of action making it challenging to control. To reduce the risk of herbicide resistance in Palmer amaranth, an integrated weed management approach must be adopted. The objective of this research was to evaluate the effect of a winter wheat cover crop and row crop cultivation on Palmer amaranth in grain sorghum. This research was conducted using small plot methods (3 m x 9 m) at Hutchinson, KS in 2017. Wheat was drilled in the fall of 2016 at 135 kg ha-1 and terminated with glyphosate at anthesis. Four treatments comprised this experiment: cover crop, row crop cultivation, cover crop plus row crop cultivation, and non-treated. The entire plot area received a burndown treatment of paraquat at grain sorghum planting; sorghum was planted on 76 cm row spacing in all treatments. The row crop cultivation occurred 1.5 wk after planting (WAP). Visual ratings at two, four and eight WAP, weed biomass, weed count and weed height were collected throughout this experiment. The results of this experiment indicate that the cover crop did not provide full season weed control. The cover crop provided almost 50% control three WAP; however, the control decreased to 15% eight WAP. The row crop cultivation provided 70% control eight WAP, although, there was not adequate suppression of the Palmer amaranth to limit seed production. The superior treatment was the cover crop plus row crop cultivation with 80% Palmer amaranth control six WAP. As a result of this research, producers and consultants should consider the use of an integrated weed control system. A cover crop or row crop cultivation alone did not provide adequate weed control which demonstrates that a combination of multiple control tactics should be utilized. When combined with a comprehensive, residual herbicide program, cultural and mechanical approaches could offer excellent Palmer amaranth control while reducing the risk of herbicide resistance.

LEGUME INTERCROPS FOR WEED SUPPRESSION IN INTERMEDIATE WHEATGRASS (THINOPYRUM INTERMEDIUM) CROPPING SYSTEMS. Joseph W. Zimbric*, Valentin D. Picasso, David E. Stoltenberg; University of Wisconsin-Madison, Madison, WI (13)

Intermediate wheatgrass (Thinopyrum intermedium) is a cool-season perennial species that has been the focus of extensive plant breeding efforts to improve several agronomic traits, the results of which have contributed to increasing market demand for its grain, Kernza®. Integrating legume intercrops into dual-purpose (grain and forage) intermediate wheatgrass (IWG) cropping systems could provide many agronomic and environmental benefits, including increased weed suppression, increased IWG grain yield and forage quality, increased nitrogen (N) cycling, and reduced soil erosion. Little is known about the effects of legumes when intercropped in IWG grain and forage systems. Our objective was to determine the effects of several legume intercrops on weed community composition, weed suppression, and IWG grain and forage yields. We hypothesized that legume intercrops would increase the competitive environment in IWG systems and reduce weed abundance and productivity. An experiment was established in the fall of 2016 at the University of Wisconsin-Madison Arlington Agricultural Research Station on a Plano silt loam soil using improved grain-type IWG (TLI-C4). The experimental design was a randomized complete block in a factorial arrangement of two IWG row spacing treatments (38 or 57 cm) and nine IWG ± intercrop treatments (four IWG monocultures: weedy check, weed free, 45 kg N ha-1, and 90 kg N ha-1, plus five IWG + legume intercrops: alfalfa, red clover, kura clover, berseem clover, soybean). Weed, IWG, and intercrop shoot biomass was measured in the spring (May), at IWG grain harvest (July), and in the fall (October). Weed densities were quantified by species biweekly from May to September. In 2017, common lambsquarters was the most abundant weed species across treatments followed by a diverse mixture of perennial, winter annual, and summer annual broadleaf species. In the spring, weed shoot dry biomass was relatively low across intercrop and row spacing treatments, and did not differ among treatments. At IWG grain harvest, weed shoot dry biomass did not differ among most treatments, except for the IWG + red clover intercrop treatment which was less (52 kg ha-1) than the IWG monoculture + 90 kg N ha-1 treatment (742 kg ha-1). Additionally, weed shoot dry biomass was less in the narrow-row than wide-row spacing treatment. Intermediate wheatgrass grain yield did not differ among most treatments, except for the IWG + kura clover (938 kg ha-1) and IWG + soybean (949 kg ha-1) treatments for which yields were greater than the

IWG + red clover treatment (725 kg ha-1). Grain yield was not affected by row spacing. At this harvest timing, IWG forage yield did not differ among monoculture and intercrop treatments, but was less in the narrow-row than wide-row spacing treatment. Fall weed shoot dry biomass was greater in the IWG weedy check (405 kg ha-1) than most other treatments, except the IWG + 45 kg N ha-1 (224 kg ha-1) and the IWG + berseem clover treatments (139 kg ha-1). As in the summer, IWG forage yield in the fall did not differ among monoculture and intercrop treatments, but was less in the narrow-row than wide-row spacing treatment. These results suggest that at the time of IWG grain harvest, weed suppression was not greatly affected by IWG monoculture or intercropping systems. Although weed suppression was greater in narrow-row spacing than wide-row spacing, IWG grain yield was not affected by row spacing.

EFFECT OF TILLAGE BY FERTILITY ON WEED COMMUNITIES IN SOUTHERN ILLINOIS OVER 48 YEARS. Sarah J. Dintelmann*1, Ron Krausz2, Karla Gage1; 1Southern Illinois University, Carbondale, IL, 2Southern Illinois University, Belleville, IL (14)

Effective soil management programs may improve soil conservation efforts and limit erosion through reduced disturbance. We hypothesize that these management actions will also impact the weed community composition over time. Our objective was to quantify the differences in weed community composition across a combination of four tillage regimes (moldboard plow, chisel plow, alternate-till (2-1-2), and no-till) and three fertility treatments (no fertilizer, nitrogen only, and nitrogen-phosphorus-potassium) following 46 yr of study implementation. Above-ground community composition as well as seedbank composition will be assessed. In previous yr throughout the 46-yr study period, weed-free conditions have been maintained with normal practices. This season, in order to quantify weed community differences, soil residual herbicides will not be applied to half of the 6 m wide plots in order to identify weed species which emerge. After weed emergence, the populations will be controlled to prevent buildup of the seedbank. To assess seedbank composition, 70 20-cm soil cores will be taken per plot. Each soil core will be separated by depth into 5cm sections, creating 4 5-cm sections. A subset of these 5 cm sections will be evaluated for soil fertility measures, and the remainder will be grown out in order to see weed emergence in each layer.

CROPPING SYSTEM DIVERSIFICATION AND PERENNIALIZATION EFFECTS ON WEED COMMUNITY COMPOSITION AND SUPPRESSION OVER 27 YEARS. Nathaniel M. Drewitz*, David E. Stoltenberg; University of Wisconsin-Madison, Madison, WI (15)

The Wisconsin Integrated Cropping Systems Trial (WICST) was initiated in 1989 and includes three grain cropping systems (conventional continuous corn, conventional corn-soybean rotation, organic corn-soybean-wheat rotation) and three forage systems (conventional corn-alfalfa rotation, organic corn-alfalfa rotation, and managed grazing). Previous WICST research has addressed yields, profitability, soil quality, carbon sequestration, and biodiversity, but effects on weed communities have not been characterized fully. Our research summarized system effects on the spring weed seedbank and late-season weed shoot biomass from 1990 to 2016. We found that seedbank densities in the organic corn-soybean-wheat system were 2- to 5-fold greater than in conventional grain systems over time (1990-2016). Similarly, seedbank densities were more than 2-fold greater in the organic corn-alfalfa system than the conventional corn-alfalfa system. Annual broadleaf weeds were most strongly associated with the conventional grain systems, whereas annual grass weeds were strongly associated with the organic grain system. Perennial, biennial, and annual weed species were associated with the forage systems. Weed biomass in the organic grain system was 17-fold greater than in the conventional grain systems over time. Similarly, total weed biomass was 10-fold greater in the organic than conventional corn-alfalfa system. Weed biomass was similar between conventional grain and forage systems over time, but was 2- to 3-fold greater in the organic grain than in the organic forage system. These results suggest that cropping system perennialization was a key factor contributing to increased weed community diversity and suppression. Although greater species richness and/or diversity occurred in organic systems, a critical tradeoff was reduced weed suppression compared to conventional systems.

CRITICAL TIME FOR WEED REMOVAL IN SOYBEAN AS INFLUENCED BY PRE HERBICIDES. Pavle Pavlovic*1, Amit Jhala2, Ethann R. Barnes2, Clint Beiermann3, Nevin C. Lawrence3, Jon E Scott4, O. Adewale Osipitan1, Stevan Z. Knezevic1; 1University of Nebraska-Lincoln, Concord, NE, 2University of Nebraska-Lincoln, Lincoln, NE, 3University of Nebraska-Lincoln, Scottsbluff, NE, 4University of Nebraska, Concord, NE (16)

Increased POST applications of glyphosate for weed control in soybean, caused rapid increase in glyphosate-resistant weeds. This led to an increased need to diversify weed control programs and use pre-emergent (PRE) herbicides with alternative modes of action. Field studies were conducted in 2015 and 2016 at Concord, NE and in 2017 at Concord and Clay Center, NE to evaluate the effects of PRE herbicides on critical time for weed removal (CTWR) in soybean. The studies were laid out in a split-plot arrangement of 14 treatments (2 herbicide regimes and 7 weed removal times), with eight (2015), and four replicates (2016 and 2017). The 2 herbicide regimes were: No PRE and PRE application of sulfentrazone plus imazethapyr at Concord across years or saflufenacil plus imazethapyr plus pyroxasulfone at Clay Center. The seven weed removal times across years and locations were: V1, V3, V6, R2 and R5 soybean growth stage, as well as weed free and weedy season long. There were statistical differences between the three years and two locations; therefore, data was presented by year and location. In 2015, CTWR (based on 5% acceptable yield loss) started at V1 soybean stage without PRE herbicide, while the PRE application of sulfentrazone plus imazethapyr (280 g ai ha-1) delayed CTWR to V5 soybean stage. The CTWR in 2016 started at V3 soybean stage without PRE herbicide, while the PRE application of sulfentrazone plus imazethapyr (210 or 420 g ai ha-1) delayed the CTWR to R1 soybean stage. In 2017 at both Concord and Clay Center, CTWR started at V1 soybean stage without PRE herbicide, while the application of PRE herbicide (sulfentrazone plus imazethapyr , 420 g ai ha-1 and saflufenacil plus imazethapyr plus pyroxasulfone , 215 g ai ha-1) delayed the CTWR to V7 soybean stage at Concord and V6 at Clay Center. These results clearly showed the benefit of using PRE herbicides to reduce the need for multiple applications of glyphosate, and provide additional mode of action for combating glyphosate-resistant weeds.

CRITICAL TIME FOR WEED REMOVAL IN CORN AS INFLUENCED BY PRE HERBICIDES. Ayse Nur Ulusoy*1, O. Adewale Osipitan2, Jon E Scott3, Stevan Z. Knezevic2; 1University of Nebraska-Lincoln, Lincoln, NE, 2University of Nebraska-Lincoln, Concord, NE, 3University of Nebraska, Concord, NE (17)

There is need to diversify weed control program by using PRE herbicides in reducing multiple POST applications of glyphosate, and to provide additional modes of action for combating glyphosate-resistant weeds in corn. Therefore, a field study was conducted in 2017 at Concord, NE, to evaluate the influence of PRE herbicides on critical time of weed removal (CTWR) in corn. The study was arranged in a split-plot design with 21 treatments; three herbicide regimes (No PRE and PRE application of two herbicides) as main plots and seven weed removal times (V3, V6, V9, V12, V15 corn growth stages as well as weed free and weedy season long) as sub-plots with four replications. The two PRE herbicides were atrazine and atrazine plus bicyclopyrone plus mesotrione plus S-metolachlor. A four parameter log-logistic model described the relationship between relative corn yields and weed removal timings. Delaying weed removal time reduced corn yield. Based on 5% acceptable yield loss threshold, the CTWR ranged from 116 to 351 growing degree days (GDD) which corresponds to V3, V5 and V9 corn growth stages, depending on the herbicide regime. Without PRE herbicide, CTWR started at V3 growth stage. PRE application of atrazine delayed the CTWR to V5 growth stage, while PRE application of atrazine plus bicyclopyrone plus mesotrione plus S-metolachlor provided the longest delay, up to V9 growth stage. These results suggested that as PRE herbicides delayed the need for POST application of glyphosate, it also provided alternative modes of action for weed control in corn.

ALLELOPATHIC EFFECTS OF PALMER AMARANTH RESIDUE ON PLANT GROWTH AND PHENOLOGY. Kayla L. Broster*1, Karla Gage1, Joseph Matthews2; 1Southern Illinois University, Carbondale, IL, 2PSAS DEPT SIUC, Carbondale, IL (19)

Illinois is an important producer of corn and soybeans, with corn accounting for more than 54% of Illinois' income from agricultural industries. Weeds, such as Palmer amaranth (Amaranthus palmeri), left uncontrolled in agriculture fields can result in crop yield loss. Palmer amaranth is becoming more common in the Midwest, and is evolving resistance to multiple herbicide modes of action. In addition to competing with crops, Palmer amaranth is known for having allelopathic interactions, potentially resulting in increased yield loss. Allelopathic effects, which are biochemical interaction between plants, have been observed between Palmer amaranth and several plant species, however, effects on corn and soybeans are unknown. Therefore, the objective of this study was to determine the allelopathy of Palmer amaranth on multiple plant species. A greenhouse study was conducted using corn and Palmer amaranth residue and four plant species. Corn residue was the control since it is known to have no allelopathic effects. Tomato germination has been shown to be sensitive to Palmer amaranth allelopathic compounds, so the tomato plants were used as comparisons. Corn, soybean, tomato, and Palmer amaranth seeds were planted in 10-cm square pots in the greenhouse, and equal amounts of corn or Palmer amaranth residues were added to the surface of the pots. The first plant to germinate was recorded and other germinating seedlings were removed to prevent competition. Growth rates were recorded for six weeks. The data indicates Palmer amaranth residue has an effect on germination and growth rate of the species tested.

BREAKING SEED DORMANCY IN PALMER AMARANTH. Samuel N. Ramirez*, Rhett Stolte, Karla Gage; Southern Illinois University, Carbondale, IL (20)

Amaranthus palmeri (Palmer amaranth) is characterized as an aggressively adaptive weed, having the ability to survive in a wide range of environments across North America, from as far south as Texas, US to as far north as Ontario, Canada. If left unmanaged, Palmer amaranth has been shown to reduce crop yields. Establishment of effective management plans for Palmer amaranth may be hindered by the presence of herbicide-resistant biotypes. Molecular assays are often used to confirm the presence of mechanisms that confer herbicide resistance. In the absence of established molecular techniques, herbicide resistance screens in the form of whole-plant assays continue to play a crucial role in the confirmation of herbicide resistance. Breaking seed dormancy has been problematic for researchers attempting to screen populations of recently collected seeds, which have not yet undergone cold stratification treatments. Therefore, this study investigates artificial methods for breaking seed dormancy in two recently-harvested Palmer amaranth seed accessions, from Belleville, IL (BRC) and Collinsville, IL (COL), to determine the most effective treatment. Following plant collection and seed cleaning, fresh seeds were treated with a 10 M concentration of sulfuric acid (H_2SO_4) at the time intervals of 2-, 5-, 10-, or 45-min exposure, or a 10-min exposure to potassium nitrate (KNO_3) at a 0.125%, 0.25%, 0.5%, or 1.0% concentration. Twenty seeds were placed on moistened filter paper in petri plates following exposure to each treatment for a total of eight replications of each combination of treatment by population. Seeds were kept moist and allowed to germinate for 21 d while daily counts were taken. A two-way ANOVA showed that there were interactive effects of population and treatment on percentage of germinating seed, indicating that the treatments did not affect BRC and COL populations in the same way. The only effective treatment for breaking dormancy in the BRC population was the two-min H2SO4 treatment (35% ± 3.5). In contrast, the treatment causing the greatest percent germination in the COL population was the 10 min H2O control treatment (33% ± 7), although this treatment effect was not different than percent germination after exposure to KNO3 at 0.125, 0.2, 0.5, 1.0% or to H20 for two min. This study demonstrates the complexities of breaking seed dormancy through artificial means and suggests that population-specific approaches to the problem of breaking seed dormancy should be explored during the planning phase of whole-plant herbicide-resistance screening assays.

METHODS OF BREAKING SEED DORMANCY IN COMMON WATERHEMP. Dustin W. Bierbaum*, Rhett Stolte, Karla Gage; Southern Illinois University, Carbondale, IL (21)

Amaranthus tuberculatus (common waterhemp) is a weed that poses a threat to crop production because of its high rate of reproduction and its potential for rapid evolution of herbicide resistance. Growers of agricultural crops must design management plans with effective herbicide sites of action; and therefore, must be able to identify herbicide-resistant weed biotypes in their fields. In the absence of molecular methods to confirm herbicide resistance, it is important to have the ability to perform herbicide resistance screens in a timely manner on plants which germinate from newly collected seed, often without the availability of the necessary time it takes to break seed dormancy using cold stratification. This study focused on measuring the effectiveness of the chemical reagents, potassium nitrate (KNO3) and sulfuric acid (H2SO4), compared to water, as possible treatments to increase germination rates for two waterhemp populations collected in the fall of 2017 in Belleville, IL (BRC) and Dowell, IL at Kuehn Research Center (KRC). KNO3 was applied to common waterhemp seed at various concentrations for a 10-min time interval at 0.125%, 0.25%, 0.5% and 1%, concentrations. H2SO4 was kept at a single concentration of 10 M, but the seed was exposed to the reagent for various time periods: 2-, 5-, 10-, and 45-min. Treated seeds were placed on filter paper in covered petri dishes and sealed with micropore tape. Petri plates were incubated in a growth chamber and exposed to a 16-hr photoperiod at 30 C. The numbers of germinating seeds were recorded every 24 hr for 21 d. Data were analyzed with a two-way ANOVA to test for the effects of population and treatment on the percentage of germinating seed. There was an interactive effect of population by treatment, indicating that treatment success may depend upon the characteristics of the species biotype. For the BRC population, H2SO4 at 2- and 5-min provided 15% ± 5 and 7.5% ± 3 germination, respectively, but these results were not different from treatments yielding 0% germination. For the KRC population, H2SO4 at a five-min exposure provided 31% ± 7 seed germination, and this treatment was not different than the two-minute H2SO4 treatment which provided 20% ± 9 seed germination. Other treatments provided 5% or less germination. This study suggests that, in the absence of pilot studies or feasibility testing for large-scale whole-plant assays for herbicide resistance screening, the exposure of waterhemp seeds to 2-min treatments of 10 M of H2SO4 may be the most reliable method tested for breaking dormancy across different populations. However, some populations, such as KRC, may reach a higher percent germination with five-min treatments of H2SO4 at the given concentration. The results of this experiment may ultimately aid researchers in conducting whole-plant assays for herbicide-resistance screening, so that effective and timely management programs may be designed for the control of common waterhemp in agricultural fields.

DENSITY-DEPENDENT JOHNSONGRASS SEED PRODUCTION UNDER DIFFERENT CROPPING SYSTEMS. Don Treptow*1, Rodrigo Werle2, Amit J. Jhala2, Melinda Yerka2, Brigitte Tenhumberg1, John Lindquist3; 1University of Nebraska - Lincoln, Lincoln, NE, 2University of Nebraska-Lincoln, Lincoln, NE, 3University of Nebraska, Lincoln, NE (22)

Understanding the population dynamics of Johnsongrass is key to predicting its expansion into new agricultural systems. An important demographic component of Johnsongrass' population dynamics is density-dependent seed production. Research was conducted in 2016 and 2017 to investigate density-dependent Johnsongrass seed production under Midwest conditions. Johnsongrass seeds from multiple infested corn, soybean, sorghum, and fallow fields from Kansas, Missouri, and Nebraska were collected. A counting square was used to determine Johnsongrass culm density, and panicles within this area were harvested. Seeds were manually threshed and counted using a seed counter. Germination of fresh seeds from each population was evaluated in a germination chamber. Viability of ungerminated seeds were further tested using the tetrazolium seed test procedure. Initial analyses indicate a nonlinear relationship between Johnsongrass culm density and seed production. The number of Johnsongrass seeds produced in each cropping system in decreasing order in 2016 was corn, soybean, fallow, and sorghum and in 2017 was sorghum, corn, soybean, and fallow. Results of this study will be used as parameter values for a risk-assessment model simulating Johnsongrass population dynamics under different crop rotations and herbicide programs.

USING SEED RAIN TO ASSESS FEASIBILITY OF AT-HARVEST SEED DESTRUCTION FOR THREE TROUBLESOME WEED SPECIES IN MISSOURI SOYBEAN. Alyssa Hultgren*1, Mandy Bish2, Sarah Lancaster3, Kevin W Bradley2; 1University of Missouri and Missouri State University, Springfield, MO, 2University of Missouri, Columbia, MO, 3Missouri State University, Springfield, MO (23)

Herbicide-resistant weeds continue to be one of the most significant problems in U.S. agricultural production. A lack of new chemistries for control of resistant weed species has resulted in the need to integrate non-chemical control methods in management programs. Harvest Weed Seed Control (HWSC) tactics are being implemented in Australia to manage herbicide-resistant weeds. More research is needed to understand the adaptability of this method in the U.S. In order for HWSC to be effective, the majority of weed seed must be retained on the seedhead at soybean harvest. This research was conducted to determine seed retention of three troublesome weeds in soybeans: common waterhemp (Amaranthus tuberculatus var. rudis), giant ragweed (Ambrosia trifida), and giant foxtail (Setaria faberi). The seed retention of the three species was determined by comparing the amount of weed seed retained on the plant at soybean maturity to the amount of weed seed shattered. In May 2016 and 2017, a 0.2 hectare area was planted to soybean with 72-cm row spacing. At time of planting, giant ragweed seedlings were transplanted between soybean rows at a minimum of two m spacing between plants. Giant foxtail and waterhemp seed were spread in two-meter increments between soybean rows, and later thinned to 0.5 plants m-1 of soybean row. As weed seedheads began to form, four collection trays (51 x 40 x 6 cm) were lined with landscape fabric and pinned to the soil at the base of 16 target plants species-1 in 2016 and 24 species-1 in 2017. Seed from each tray were collected once wk-1. In 2016, giant foxtail seed began to shatter on August 19th but this occurred one wk later in 2017. In both years, giant ragweed and waterhemp began seed shatter the wk of September 19th when soybean had reached R7 maturity. In 2016, counts of seed shatter were carried out until five wk following soybean maturity. One wk after soybean had reached R8, approximately 70% of giant ragweed seed, 88% of common waterhemp seed, and 75% of giant foxtail seed remained on the plants. By five wk following soybean senescence, approximately 35% of giant ragweed seed, 52% of common waterhemp seed, and 5% of giant foxtail seed remained intact. These measurements are being repeated in 2017. Initial results suggest that HWSC may be a useful tactic in controlling some but not all problematic weed species. This research is part of a larger United States Department of Agriculture- Agricultural Research Service (USDA-ARS) area wide project focused on managing herbicide resistance (www.integratedweedmanagement.org).

EFFECT OF DEGREE OF WATER STRESS ON THE GROWTH AND FECUNDITY OF PALMER AMARANTH. Parminder Chahal*, Suat Irmak, Amit Jhala; University of Nebraska-Lincoln, Lincoln, NE (24)

Palmer amaranth is the most problematic weed in agronomic crop production fields in the United States. The objective of this study was to determine the effect of degree of water stress on the growth and fecundity of two Palmer amaranth biotypes under greenhouse conditions. Palmer amaranth plants were grown in the soil maintained at 100, 75, 50, 25, and 12.5% soil field capacity (FC) corresponding to no, light, moderate, high, and severe water stress, respectively, using irrigation sensors in 20 cm wide and 40 cm deep plastic pots. Water was regularly added to soil based on moisture level detected by sensors to maintain desired water stress levels. No difference was observed in the growth and seed production between Palmer amaranth biotypes and experimental runs; therefore, data were combined over biotypes and experimental runs. Palmer amaranth plants maintained at ≤ 25% FC did not survive more than 35 d after transplanting and were not able to produce seeds. Plants at 100% FC achieved maximum height of 178 cm compared to 124 cm height at 75% FC and 88 cm at 50% FC. In contrast, water stress treatments did not affect the maximum number of leaves produced (588 to 670 plant−1), except 25 and 12.5% FC (60 to 68 leaves plant−1). The total leaf area produced plant−1 at harvest was also similar (571 to 693 cm2 plant−1) at 100, 75, and 50% FC. Likewise, dry leaf biomass was similar (5.4 to 6.4 g plant−1) among 100, 75, and 50% FC at harvesting; however, 25 and 12.5% FC plants produced only 1.2 to 1.4 g leaf biomass because plants died early in the season resulting in less number of leaves produced plant−1. Palmer amaranth produced similar root biomass of 2.3 to 3 g plant−1 at 100, 75, and 50% FC compared to 0.6 to 0.7 g plant−1 at 25 and 12.5% FC. Similarly, the growth index did not vary (1.1 to 1.4 × 105 cm3 plant−1) among 100, 75, 50% FC treatments. The seed production was greatest (42,000 seeds plant−1) at 100% FC produced compared to 75 and 50% FC (14,000 to 19,000 seeds plant−1). Additionally, germination test was accomplished on harvested seeds to determine effect of water stress on germination. A cumulative seed germination was similar (18 to 26%) when plants were exposed to ≥ 50% FC. This study shows that Palmer amaranth has capacity to survive and produce seeds even under moderate water stress conditions.

WATERHEMP SEED PRODUCTION AND SEED VIABILITY AS AFFECTED BY SUBLETHAL DICAMBA DOSE. Allyson Rumler*1, Brent Heaton2, Mark Bernards1; 1Western Illinois University, Macomb, IL, 2Western Illinois University, Industry, IL (25)

Waterhemp (Amaranthus tuberculatus) is a problematic weed across the Midwest because it has evolved resistance to multiple herbicide mechanisms of actions. Dicamba herbicides for dicamba-resistant soybeans (Glycine max) were commercialized in 2017 and were adopted by many to help manage herbicide-resistant weed populations. Solo applications of dicamba may be expected to provide 85% control of waterhemp. Every dicamba application includes the risk that some waterhemp plants will be exposed to sublethal doses of dicamba and will survive to produce seed. Sub-lethal dicamba doses applied during reproductive growth stages to soybean or Phaseolus vulgaris resulted in reduced seed germination. The objectives of this study were to 1) measure the relationship between dicamba dose and waterhemp seed production and to 2) determine if dicamba dose affects the percentage of viable seed. Seed from a waterhemp population that was segregating for resistance to glyphosate, atrazine, ALS- and PPO-inhibiting herbicides was collected from the WIU AFL Agronomy Farm in the fall of 2015. Seed was planted into potting mix (BX Pro-Mix with Biofungicide and Mycorrhizae) in 30 x 60 cm trays on 2/14/2017. Plants were grown in the WIU School of Agriculture Greenhouse, with a 16:8 day:night light regime, and day temperatures of 27 ± 3 C and night temperatures of 20 ± 3 C. Plants were transplanted into 7.6 x 7.6 x 15.2 centimeter plastic pots, and were subsequently thinned to three waterhemp plants per pot. Plants were sorted according to height, and divided into two groups 1) 10-15 cm and 2) 20-25 cm. There were ten replications and six dicamba doses: 560, 280, 140, 70, 18.4 and 0 g ae ha-1. Dicamba was applied on 3/30/2017 using a spray chamber calibrated to apply 187 L ha-1 through 8002EVS nozzles.

Leaf node number was recorded for each plant on 4/5/2017. Visual injury estimates on a scale of 0 (no injury) to 100 (plant death) were made approximately a month after herbicide application. Sex identification, mortality and seed production assessments were made 7/7/2017. Waterhemp was harvested by hand (8/3-7/2017) and seed threshed, filed into their corresponding envelope, weighed, and stored in the fridge at 6.1 C until germination studies began. To test germination, approximately 50 seeds were placed in petri dishes (5.5 cm) in 8 mL of deionized water. Each petri dish was wrapped with parafilm and placed in a germination chamber for 144 hr at 29.4 C to 32.2 C. Seeds were strained over a cheese cloth to remove deionized water and count germinated seeds. Seeds that did not germinate were dissected longitudinally under a dissecting scope and placed embryo-side down in a petri dish with a filter paper moistened with 2 mL of 1% (w v-1) tetrazolium solution. Petri dishes were wrapped in aluminum foil to reduce light exposure sat for 24 hr at room temperature after which seeds were evaluated for viability (indicated by a pink embryo). Visual injury estimates, seed production, seed weight, and germination/viability were subjected to ANOVA, and where appropriate fit to functions to quantify the effect of dose. Waterhemp injury and mortality increased as dicamba dose increased to the max does applied. However, there were individual plants within each dicamba dose treatment that produced seed.

EFFICACY OF GLYPHOSATE AND DICAMBA ON KOCHIA AND RUSSIAN THISTLE AS INFLUENCED BY DROUGHT AND DUST CONDITIONS. Jeffrey Golus*1, Kasey Schroeder1, Greg R Kruger2; 1University of Nebraska-Lincoln, North Platte, NE, 2University of Nebraska, North Platte, NE (26)

A common rainfed crop rotation in the High Plains of the United States is winter wheat – corn – fallow. No-till has been adopted on many hectares as a means to increase infiltration of rainfall events, reduce both water and wind erosion and to reduce evaporation of soil-stored water. As a result, producers rely heavily on postemergence herbicides to control weeds in the absence of tillage, especially during fallow periods. These are primarily late summer after wheat harvest, and spring and summer before wheat planting. During the post-wheat harvest fallow period (July to September) temperatures are typically very warm and rainfall is generally lower, resulting in drought conditions. Dusty conditions and drought stressed weeds are commonly observed, and reduced control of weeds is a concern. A greenhouse study was conducted to examine the effects of dust and drought stress conditions on the efficacy of glyphosate and dicamba on kochia and Russian thistle, two common weed species in rainfed cropping systems in the High Plains. Our study showed that heavy dust can significantly limit the efficacy of both glyphosate and dicamba, but drought conditions in the absence of dust seem to have little effect on the efficacy of either herbicide.

INVESTIGATING THE FITNESS COST OF DICAMBA RESISTANCE IN KOCHIA. Chenxi Wu*1, Sherry LeClere2, Philip Westra3, R. Douglas Sammons2; 1Monsanto Company, St Louis, MO, 2Monsanto, Chesterfield, MO, 3Colorado State University, Fort Collins, CO (27)

Fitness costs of herbicide-resistance traits are important parameters for both modelling the evolution of herbicide resistance and developing herbicide resistance mitigation strategies. Fitness cost of resistance to synthetic auxins has been measured before without knowing the genetic basis of the resistance mechanism and thus, directly attributing the difference in fitness among different populations to resistance was difficult and imprecise and the dominance of the fitness cost for dicamba resistance was not possible to determine. Recently, dicamba resistance in a kochia (Kochia scoparia) line from western Nebraska was found to be conferred by a point mutation controlled by a single dominant gene. An allele specific Taqman assay was successfully developed and utilized in a greenhouse replacement series study to compare the fitness among different genotypes of this Kochia population. Our study agrees with the previous finding that there is a significant fitness cost associated with dicamba resistance in kochia. Our study clearly showed that the fitness costs were manifested in only certain growth stages: No differences were observed in germination rate, root length and seedling mortality; however, homozygous sensitive (SS) plants had higher relative growth rate resulting in taller plants, accumulated more above-ground biomass and produced more seeds than heterozygous (RS) and homozygous resistant (RR) plants. The calculation of the dominance of the fitness cost of dicamba resistance in kochia based on seed production under competition conditions, indicates the fitness cost of the mutation that endows resistance ranges from semi-dominant (0.5) to dominant (1). This study also suggests that the fitness cost of dicamba resistance in kochia might vary with competition levels and the environmental conditions (e.g. water supply, photoperiods) since the fitness cost was manifested to a greater extent when the RR or RS plants were challenged with competition from SS plants.

INVESTIGATION OF HERBICIDE-RESISTANT ITALIAN RYEGRASS IN WESTERN KENTUCKY. Zachary K. Perry*1, Travis Legleiter2; 1University of Kentucky, Lexington, KY, 2University of Kentucky, Princeton, KY (28)

Italian ryegrass (Lolium multiflorum) is a major pest for Kentucky wheat growers. A ryegrass population with suspected glyphosate resistance was identified in western Kentucky. Dose response experiments with a randomized complete block design with five replications were conducted in the greenhouse using rates of glyphosate ranging from 55 g ha-1 to 13798 g ha-1. A spray chamber with an 8002EVS nozzle traveling at 2.57 kph and pressure of 152 kPa was used to make applications to a susceptible (SUS) and a suspected resistant (BART) ryegrass biotype. Visual ratings were recorded three wk after application on a scale of 0-100 with zero being no injury and 100 plant death. Counts of surviving plants pot-1 were taken at three wk after application as well as biomass harvest and fresh weight. Dose response curves and ED50 for visual control, percent survival and percent fresh weight of the control were modeled using the drc package in R software. Visual control ratings for the SUS population had an ED50 of 536 g ha-1, whereas the BART population had an ED50 of 2110 g ha-1. The fresh weight ED50 for the SUS population was 236 g ha-1 and1069 g ha-1 for the BART population. Lastly, the percent survival ED50 was 854 g ha-1 for the SUS population and 1786 g ha-1 for the BART population. The ED50 values for all measurements were different between the SUS and BART biotype. Results from this initial dose response experiment would indicate that glyphosate does suppress the growth of the BART ryegrass biotype, although dosages within this experiment were not great enough to provide lethal dosages to this biotype. Initial experiment results indicate that there is likely glyphosate resistance in the BART biotype, although further experimental runs and reproductive viability of surviving plants need to be evaluated.

SORTING THROUGH MULTIPLE MECHANISMS OF PPO-INHIBITOR RESISTANCE IN PALMER AMARANTH AND WATERHEMP. Kathryn Lillie*1, Darci Giacomini1, James R Martin2, J D Green3, Patrick Tranel1; 1University of Illinois, Urbana, IL, 2University of Kentucky, Princeton, KY, 3University of Kentucky, Lexington, KY (29)

The first known mechanism of resistance to PPO-inhibiting herbicides in Amaranthus spp. involves the loss of a glycine at position 210 in the mitochondrial isoform of the PPO enzyme (ΔG210). The second known mechanism results in an amino acid change from arginine to glycine or methionine at position 128 of the PPO enzyme (R128G, R128M). In 2015, a single field in Kentucky was found to contain both A. palmeri and A. tuberculatus that exhibited PPO-inhibitor resistance. Originally, the ΔG210 mutation was the only mechanism thought to be conferring resistance in this field, but upon further analysis, it was found that the R128 mutation was also present in the A. palmeri population. Consequently, this study was carried out to determine the prevalence of each mutation in the A. palmeri population, as well as to characterize the relative levels of resistance to PPO inhibitors in A. palmeri and A. tuberculatus conferred specifically by the ΔG210 mutation. Progeny from A. palmeri plants collected from this field were sprayed at a discriminatory dose and the survivors were assayed to determine which mutations they possessed, and then a dose response study was carried out on both A. palmeri and A. tuberculatus at early and late POST timings. The results indicate that A. palmeri is more tolerant than A. tuberculatus to PPO-inhibiting herbicides, especially when sprayed at a later timing. Additionally, the ΔG210 and R128G mutations are present in 40% and 27% of the A. palmeri plants sprayed, respectively. The increased tolerance to PPO inhibitors coupled with the presence of both resistance mutations in this A. palmeri population highlight challenges for effective control of this species with PPO-inhibiting herbicides.

INHERITANCE OF MESOTRIONE RESISTANCE IN A WATERHEMP POPULATION FROM NEBRASKA. Maxwel C. Oliveira*1, Todd A. Gaines2, Stevan Z. Knezevic1; 1University of Nebraska-Lincoln, Concord, NE, 2Colorado State University, Fort Collins, CO (30)

A population of waterhemp (Amaranthus tuberculatus var. rudis) evolved resistance to 4-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibitor herbicides (mesotrione, tembotrione, and topramezone) in Nebraska. The level of resistance was the highest to mesotrione, and the mechanism of resistance in this population is metabolism-based, likely via cytochrome P450 enzymes. The increasing number of weeds resistant to herbicides warrants studies on the ecology and evolutionary factors contributing to resistance evolution, including inheritance of resistance traits. The objectives of this study were to evaluate the inheritance and herbicide resistance segregation pattern in mesotrione-resistant waterhemp from Nebraska, US. Results showed that inheritance of mesotrione resistance in waterhemp is complex. The reciprocal cross in the F1 families exhibited nuclear inheritance, which allows seed and pollen movement carrying herbicide resistance alleles. In F1 families, the mode of inheritance varied from near additive to moderately high incomplete dominance. Observed segregation patterns for the majority of the F2 and back-cross susceptible (BC/S) families did not fit to a single major gene locus model. Therefore, multiple genes are likely to confer metabolism-based mesotrione resistance in this waterhemp population from Nebraska. The results of this study provided an understanding of the genetics and inheritance of a non-target-site based mesotrione-resistant waterhemp population.

FREQUENCY OF TARGET-SITE RESISTANCE AND SUSCEPTIBILITY TO ALS-INHIBITING HERBICIDES IN INDIANA WATERHEMP POPULATIONS. Jodi E. Boe*, Haozhen Nie, Bryan G. Young; Purdue University, West Lafayette, IN (31)

Tall waterhemp (Amaranthus tuberculatus) is one of the most troublesome weeds throughout the Midwestern US due to widespread infestations and propensity for evolving resistance to herbicides. Tall waterhemp has evolved resistance to six different sites of action and biotypes have been reported to have multiple resistance to five sites of action. In Indiana, tall waterhemp with multiple resistance to glyphosate, group #2, and group #14 herbicides has raised concern over the utility of POST-applied herbicides for soybean production. This is especially true for group #2 herbicides, as resistance to this site of action has contributed to the mindset that group #2 herbicides have little value in tall waterhemp populations today. When group #2 herbicides are left out of applications, their potential to control susceptible individuals goes unrealized. Field surveys conducted in the past have shown that, despite the prevalence of group #2-resistant tall waterhemp populations, susceptible individuals remain within these populations. To determine the frequency of tall waterhemp plants that remain susceptible to group #2 herbicides within and across field populations in Indiana, a survey was conducted in September of 2017. Field collections were taken in counties that have past confirmed presence of group #2-resistant tall waterhemp. Two fields from each surveyed county were selected and sampled based on the presence of high tall waterhemp densities. Sampling consisted of selecting seed heads from five random waterhemp plants within the field. Seed was then grown in the greenhouse and fifty emerged tall waterhemp were tissue sampled for DNA extraction. A TaqMan® probe was developed to detect the Trp-574-Leu (W574) single-nucleotide polymorphism on the ALS gene that confers resistance to three families of group #2 herbicides: imidazolinones, sulfonylureas, and triazolopyrimidines. W574L is the only reported SNP on the ALS gene that confers cross-resistance to multiple group #2 families. Populations were assayed for the absence or presence of the W574L mutation and at what level: heterozygous or homozygous. Results from this survey have shown that some populations of tall waterhemp in Indiana consist of individuals without the W574L mutation. In populations segregating for group #2 resistance with and without the W574L mutation, group #2 herbicides may still provide value in weed management plans. Further research is currently underway to detect and quantify the presence of two other SNPs reported to confer resistance to group #2 herbicides in waterhemp, Ser-653-Asn and Ser-653-Thr.

ARTIFICIAL HYBRIDIZATION BETWEEN AMARANTHUS TUBERCULATUS AND AMARANTHUS ALBUS. Brent Murphy*1, Laura A. Chatham2, Patrick Tranel1; 1University of Illinois, Urbana, IL, 2University of Illinois, Champaign, IL (32)

Multiple species within the Amaranthus genus have been reported to cross pollinate, resulting in the formation of interspecific hybrids. Amaranthus spinosus has been documented to have obtained glyphosate resistance through interspecific hybridization with closely related A. palmeri. Furthermore, gene flow between subgenera has been documented in both field and lab settings, such as the unidirectional gene flow observed from A. tuberculatus to A. hybridus. Here we outline the hybridization potential between A. tuberculatus and A. albus under greenhouse conditions. Utilizing ALS-inhibitor resistance as a selectable marker present within the A. tuberculatus population, progeny of eight A. albus plants grown with A. tuberculatus were screened for candidate hybrids, which were confirmed with molecular markers. Progeny from four A. tuberculatus female plants grown with A. albus were screened for the presence of A. albus diagnostic molecular markers. Infrequent unidirectional hybridization from A. tuberculatus to A. albus was observed. Both sterile and dioecious fertile hybrid plants were obtained. Interestingly, A. tuberculatus female progeny produced skewed gender ratios, favoring the female gender. Potential causes of this phenomenon are discussed, such as auto-pollination and apomixis.

EVALUATION OF ACCASE-INHIBITOR AND GROWTH REGULATOR HERBICIDE TANK-MIXTURES. Bonheur Ndaysihimiye*1, Jeffrey Golus2, Kasey Schroeder2, Bruno Canella Vieira3, Andre O. Rodrigues2, Greg R Kruger4; 1University of Nebraska-Lincoln, Lincoln, NE, 2University of Nebraska-Lincoln, North Platte, NE, 3University of Nebraska, Lincoln, NE, 4University of Nebraska, North Platte, NE (33)

Pesticide applications of growth regulator herbicides with ACCase-inhibiting herbicides is becoming much more common. While the growth regulator herbicides effectively control broadleaf weeds and ACCase-inhibitors effectively control monocotyledonous weeds, the tank-mixtures of the two herbicide groups have been reported to cause antagonism in volunteer corn in certain situations. The objective is this study was to evaluate growth regulator herbicides with ACCase-inhibitors to determine if the tank-mixtures were antagonistic, synergistic or additive. A randomized complete block design with four replications was utilized in a field study at the West Central Research and Extension Center within the University of Nebraska-Lincoln near North Platte, NE. Plots were sprayed using a backpack sprayer to deliver 94 L ha-1. TTI110015 nozzles were operated at 276 kPa on a 50-cm nozzle spacing. Plots consisted of planted rows of oats (Avena sativa), rye (Secale cereale), grain sorghum (Sorghum bicolor), and velvetleaf (Abutilon theophrasti Medik.) with a natural population of bristly foxtail (Setaria verticillata (L.) Beauv.). Four ACCase inhibitors (clethodim, fluazifop, quizalofop, and sethoxodim) were evaluated at three rates each (low, medium and high, in respect to the maximum and minimum labeled rates) alone and in combination with either dicamba or 2,4-D. Dicamba and 2,4-D were also applied alone. Data were analyzed using the Colby equation to determine synergism, antagonism and additivity. No synergistic responses were observed across combinations of ACCase-inhibiting herbicides and growth regulator combinations. For velvetleaf, an additive response was observed across the ACCase-inhibiting herbicides indicating the ACCase-inhibiting herbicides do not antagonize the activity of either 2,4-D or dicamba on this species (the only broadleaf weed observed in this study). However, for all of the monocotyledonous plants in this study, there were both additive and antagonistic responses depending on the growth regulator, ACCase-inhibitor and the rate of the ACCase inhibitor used. Dicamba had a predominantly antagonistic effect on clethodim across rate for oats, rye, grain sorghum and bristly foxtail while 2,4-D had a predominantly additive effect on oats, rye and grain sorghum and antagonism for bristly foxtail. For fluazifop, there was a predominantly antagonistic effect from dicamba on oats and bristly foxtail while there was a predominantly additive effect for rye and grain sorghum. For fluazifop, there was also a predominantly antagonistic response from tank-mixtures with 2,4-D on oats, grain sorghum and bristly foxtail while on rye was additive. Quizalofop tank-mixtures with dicamba had a predominantly antagonistic effect on oats and bristly foxtail while on rye and grain sorghum were predominantly additive. Quizalofop tank-mixtures with 2,4-D were predominantly antagonistic for all four grass species. Sethoxydim, interestingly, was predominantly additive across all four grass species for tank-mixtures with 2,4-D and dicamba. In summary, if antagonism is a potential concern, applicators should look at using sethoxydim since there appear to be less combinations where antagonism was observed. Furthermore, higher rates of the ACCase-inhibiting herbicides generally reduced the frequency of antagonism across grass species.

EFFECTS OF GLYPHOSATE, GLUFOSINATE, AND DICAMBA TANK-MIXTURES. Rodger Farr*1, Jeffrey Golus1, Greg R Kruger2; 1University of Nebraska-Lincoln,

North Platte, NE, 2University of Nebraska, North Platte, NE (34)

As seed and chemical companies stack more and more traits to combat evolving weed species, producers look to tank mix these herbicides to save application costs. It is important to understand how these certain chemicals interact with each other in a tank mix environment. This study evaluated the effects that glyphosate, glufosonate, and dicamba had on each other when mixed together in multiple different tank mix combinations and sprayed over common Western Nebraska weeds. The study included three herbicides (glyphosate, glufosinate, and dicamba) sprayed as standalone applications plus all the different combinations of the three herbicides in two-way mixtures as well as a three-way mix of all three herbicides. These tank mixes were repeated at the herbicides' full label rate, half label rate, and quarter label rate. The tank-mixes were applied to six different species: kochia (Kochia scoparia), grain sorghum (Sorghum bicolor), velvetleaf (Abuliton theophrasti), and horseweed (Conyza canadensis). This study was replicated twice, once at Gothenburg, NE and again at North Platte, NE. Herbicide injury was taken at 7, 14, 21, and 28 days after treatment on all species. Herbicide interaction was analyzed according to the Colby method where it was determined if the tank mixes showed antagonistic, synergistic, or additive action. When looking at data, it could be observed that most combinations showed additive action while the tan mix of dicamba and glufosinate generally showed antagonistic properties at the lower rates.

INTERACTION OF HPPD-INHIBITING HERBICIDES WITH GLYPHOSATE, GLUFOSINATE, 2,4-D AND DICAMBA. Vera Vukovic*1, Jeffrey Golus1, Kasey Schroeder1, Greg R Kruger2; 1University of Nebraska-Lincoln, North Platte, NE, 2University of Nebraska, North Platte, NE (35)

Using two or more herbicides in same tank-mixture is often beneficial, but sometimes it can cause unexpected effects. When two herbicides are mixed, their activity can be higher than expected based on the activity of both herbicides applied alone (synergism), lower than expected (antagonism), or activity can be at the expected level (additive). The objective of this study was to determine if the interactions between HPPD-inhibitors and glyphosate, glufosinate, 2,4-D or dicamba on the control of weeds are synergistic, antagonistic, or additive. Plant species used in this study were glyphosate-resistant Palmer amaranth (Amaranthus palmeri), common lambsquarters (Chenopodium album (L.)), and grain sorghum (Sorghum bicolor (L.)). Plants were grown in the greenhouse at the UNL-WCREC in North Platte, NE and sprayed using three-nozzle, laboratory track sprayer. Five herbicides (mesotrione, glyphosate, glufosinate, 2,4-D, and dicamba) were examined alone and in tank mixture-combinations. Mesotrione was applied at five different rates: 0.03, 0.05, 0.1, 0.2 and 0.42 kg ae ha-1. Rates of other herbicides which were used were: dicamba at 0.76 kg ae ha-1, 2,4-D at 1.01 kg ae ha-1, glufosinate at 1.01 kg ae ha-1, and glyphosate at 1.11 kg ae ha-1. At the time of application, plants were 10 to 15 cm tall. Treatments were made at 94 L ha-1 and applications were made by using TTI11004 nozzles at 276 kPa and 19 km hr-1. The study was conducted with five individual plants treatment-1 in each of two experimental runs. Visual estimations of injury were collected for individual plants at 7, 14, 21 and 28 d after application. Fresh weights of plants were recorded, as well as dry weights, after drying to constant mass. Results have shown signs of synergism between glyphosate and mesotrione on Palmer amaranth plants. Also, synergistic interaction between mesotrione and glufosinate were observed on common lambsquarters. Addition of dicamba to mesotrione caused antagonistic reactions on sorghum, but addition of 2,4-D caused improved control on the same species.

RESISTANCE TO CARFENTRAZONE-ETHYL IN TALL WATERHEMP. Olivia A. Obenland*1, Rong Ma2, Sarah O'Brien3, Anatoli V. Lygin1, Dean E Riechers4; 1University of Illinois at Urbana-Champaign, Urbana, IL, 2University of Illinois, Urbana, IL, 3University of Illinois at Urbana-Champaign, Urban, IL, 4Univ of Illinois Crop Science, Urbana, IL (36)

The only reported mechanism conferring protoporphyrinogen oxidase (PPO) resistance in waterhemp (Amaranthus tuberculatus) is the ΔG210 codon deletion in the gene encoding the PPO enzyme, PPX2L, which results in cross-resistance to all classes of foliar PPO-inhibiting herbicides. However, a waterhemp population from Stanford, Illinois (termed SIR) was suspected of having a different target-site mutation or potentially a non-target site resistance (NTSR) mechanism. Initial speculation was based on the population's postemergence (POST) resistance to carfentrazone-ethyl (CE), an aryl-triazinone, but typical sensitivity to other PPO inhibitors classes, such as diphenylethers (DPEs), applied POST. The objectives of this research were to (1) screen a variety of PPO inhibitors and perform a dose-response study of CE on different waterhemp populations to characterize the levels of POST resistance in SIR, and (2) sequence nearly full-length PPX2L cDNAs from SIR to compare with other populations in order to determine if SIR possesses the ΔG210 glycine deletion or an arginine substitution that had been previously found in palmer amaranth (Amaranthus palmeri). Screening these populations with a CE rate labeled for waterhemp control showed that SIR sustained significantly less injury than two PPO-sensitive populations (WCS and SEN) but was comparable to a known PPO-resistant population (ACR) possessing the ΔG210 mutation. However, SIR was controlled with labeled rates of POST herbicides belonging to the DPE and pyrimidinedione classes of PPO inhibitors. Dose-response analysis determined rates of CE causing 50% growth reductions (GR50) in each resistant (R) or sensitive (S) population. Using these GR50 values, fold-resistance ratios (R/S) to CE showed SIR was approximately 30 fold-resistant compared to SEN and two-fold more resistant than ACR. The deduced amino acid sequences of PPX2L derived from several reverse-transcriptase PCR products amplified from the SIR cDNA did not reveal the typical ΔG210 mutation found in ACR. However, several SIR cDNAs contained amino acid substitutions, but none were uniform across all sequences and thus did not correlate with resistance to CE. This finding indicates that CE resistance in SIR is likely conferred through mechanisms other than target-site mediated resistance, such as enhanced metabolism via cytochrome P450s; however, PPX2L expression and copy number also need to be examined. In conclusion, SIR possesses high-level resistance specific to CE that is not due to the ΔG210 mutation in PPX2L and resistance is likely not target-site mediated. By contrast, resistance is more likely conferred through a NTSR mechanism such as enhanced oxidative metabolism.

TALL WATERHEMP RESISTANCE TO PPO-INHIBITING HERBICIDES: DOES S-METOLACHLOR REDUCE SELECTION PRESSURE, DECREASE OVERALL SURVIVORSHIP, OR BOTH? Brent C. Mansfield*1, Haozhen Nie1, Julie M Young2, Bryan G. Young1; 1Purdue University, West Lafayette, IN, 2, Brookston, IN (37)

The use of protoporphyrinogen oxidase (PPO)-inhibiting (group #14) herbicides in soybean production has increased dramatically in recent years to manage tall waterhemp (Amaranthus tuberculatus syn. rudis) populations with resistance to glyphosate. An increase in group #14 herbicides continues to be disconcerting because of the increase in selection pressure for group #14-resistant biotypes. Previous research has demonstrated that the use of soil residual group #14 herbicides, including fomesafen, can increase the frequency of the PPO-resistance trait (ΔG210 deletion) in tall waterhemp plants that escape the residual herbicide. In addition, combining s-metolachlor as an alternative site of action with fomesafen did not affect this increase in the PPO-resistance trait when the rate of the two herbicides were applied at a constant ratio. We hypothesized that the length of effective soil residual activity of the alternate herbicide site of action relative to the length of soil residual from fomesafen will influence the frequency of the PPO-resistance trait in the surviving weed population. A total of three field trials, one in 2016 near Lafayette and two in 2017 near Lafayette and Farmland, Indiana, were conducted in a population of tall waterhemp with two different frequencies of the PPO-resistance trait. Herbicide treatments included a factorial of four rates each of fomesafen (0, 66, 132, 264 g ai ha-1) and s-metolachlor (0, 335, 710, 1420 g ai ha-1) applied preemergence to a weed-free, stale seedbed. The first 25 waterhemp plants to emerge (i.e. escape) after treatment were collected for genotypic analysis to determine the ratio of resistant and susceptible surviving plants. Visual assessments of overall plot control were evaluated once weekly from 14 to 42 d after treatment (DAT). Weed density was recorded 28 and 56 DAT. Due to no effect for weed density or visual control across site years, data were pooled together for the trials near Lafayette. The number of tall waterhemp plants collected at 28 DAT varied across sites and years with some treatments having no emergence (survivors). Weed density was less near Farmland with no differences between treatments at 56 DAT. The interaction of fomesafen and s-metolachlor was significant at all locations. More specifically, the influence of s-metolachlor rate on control of tall waterhemp diminished as the rate of fomesafen increased. Both the extent of weed control and the frequency of resistance traits in the surviving weed population must be considered in determining the value of herbicide combinations for resistance management.

RAPID METABOLISM CONTRIBUTES TO ATRAZINE RESISTANCE IN COMMON WATERHEMP FROM NEBRASKA. Amarnath R. Vennapusa*1, Felipe Faleco2, Bruno Vieira3, Spencer Samuelson4, Greg R Kruger5, Rodrigo Werle6, Mithila Jugulam1; 1Kansas State University, Manhattan, KS, 2University of Nebraska Lincoln, North Platte, NE, 3University of Nebraska, Lincoln, North Platte, NE, 4University of Nebraska, Lincoln, NE, 5University of Nebraska, North Platte, NE, 6University of Nebraska-Lincoln, Lincoln, NE (38)

Resistance to atrazine (a photosystem II-inhibitor) is prevalent in common waterhemp (Amaranthus tuberculatus) across the Midwestern US. Previous research suggests that rapid metabolism of atrazine mediated by glutathione S-transferase (GST) conjugation confers resistance in common waterhemp from IL. The distribution and mechanism of resistance to atrazine in common waterhemp populations from NE is unknown. The objectives of this research were to a) evaluate the efficacy of atrazine to control common waterhemp populations from NE when applied as PRE and POST, and b) determine the mechanism of atrazine resistance in NE populations. Results from the PRE and POST greenhouse screenings indicate that atrazine was not effective on 43% and 68% of the common waterhemp populations evaluated (total of 106 and 85 populations), respectively, suggesting prevalence of atrazine resistance in common waterhemp in NE. The chloroplastic psbA gene, coding for D1 protein (target site of atrazine) was sequenced using DNA extracted from 85 plants representing 27 populations of common waterhemp. Furthermore, 24 plants selected randomly from four atrazine-resistant populations were also used to determine the metabolism of atrazine via GST conjugation. The results indicate no known point mutation in psbA gene resulting in serine264glycine substitution for atrazine resistance. However, the resistant plants conjugated atrazine faster than the known atrazine-susceptible plants via GST activity. Overall, the outcome of this study clearly demonstrate the predominance of metabolism-based resistance to atrazine in common waterhemp from NE, which may predispose this species to evolve resistance to other herbicide families. The use of integrated weed management strategies for common waterhemp is crucial for sustainable management of this troublesome species.

RAPID METABOLISM INCREASES RESISTANCE TO 2,4-D IN COMMON WATERHEMP UNDER HIGH TEMPERATURE. Chandrima Shyam*1, Junjun Ou2, Greg R Kruger3, Mithila Jugulam1; 1Kansas State University, Manhattan, KS, 2Kansas State Univ., Dep of Agronomy, Manhattan, KS, 3University of Nebraska, North Platte, NE (39)

Evolution of resistance to multiple herbicides in common waterhemp throughout the Midwestern US reduces the efficacy of many herbicides; nonetheless, 2,4-D is a valuable post-emergence option for controlling this weed. In 2009 evolution of resistance to 2,4-D in common waterhemp was documented in NE. Our previous research suggests that the metabolism of 2,4-D contributes to resistance in this common waterhemp. Herbicide efficacy and level of resistance are known to be influenced by growth temperature. The objective of this research was to investigate the effect of growth temperature on the efficacy of 2,4-D in 2,4-D-resistant (R) and -susceptible (S) common waterhemp. R and S plants were grown under two temperature regimes, i.e., 34/20 (HT) and 24/10 (LT) oC (d/n) with 15/9 (d/n) hr photoperiod in separate growth chambers. 2,4-D-dose-response study was conducted by spraying 10-12 cm plants. Additionally, to assess the effect of temperature on physiological processes, [14C] 2,4-D absorption, translocation and metabolism experiments were also conducted at 24 and 72 hr after treatment (HAT). The result of the dose-response study revealed that common waterhemp (both R and S) was more sensitive to 2,4-D with greater injury and decreased biomass accumulation under LT than HT. While there was no difference in [14C] 2,4-D absorption, or translocation between R and S grown under both temperature regimes, yet, at 24 HAT, R plants metabolized more 2,4-D under HT, than LT. On the other hand, S plants retained the majority of parent 2,4-D both at HT and LT. These results suggest that resistance to 2,4-D in common waterhemp can be increased at high temperatures as a result of rapid metabolism of 2,4-D. Therefore, to increase the efficacy of 2,4-D and better control of common waterhemp, POST applications can be made when the temperature is cooler.

QUALIFICATION OF EPSPS GENE DUPLICATION FOR GLYPHOSATE RESISTANCE IN PALMER AMARANTH. Chenxi Wu*1, Zoee Perrine2, Brian D. Eads2, Geliang Wang2, R. Douglas Sammons3; 1Monsanto Company, St Louis, MO, 2Monsanto, St Louis, MO, 3Monsanto, Chesterfield, MO (40)

Massive amplification and insertion of EPSPS (5-enolpyruvylshikimate-3-phosphate synthase) gene across the genome, has been believed to fully account for glyphosate resistance (GR) in Palmer amaranth (Amaranthus palmeri) since 2010 (Gaines et al.). It was later shown that other putative genes were also amplified in addition to EPSPS gene, challenging the conclusions that EPSPS was the sole mechanism for glyphosate resistance. What is more, in the glyphosate resistant Palmer population from GA whose resistance mechanism was first described to be EPSPS amplification, we observed plants with high EPSPS copy numbers that are sensitive to glyphosate. To elucidate the genetic difference that causes different sensitivities, high-EPSPS-copy resistant (HC_R) and high-EPSPS copy sensitive (HC_S) plants were characterized at the genomic DNA, protein and RNA levels (q-PCR, western/northern blot, and RNA-Seq) in different plant tissues as well as, before and after glyphosate treatment. Our preliminary results show that both HC-R and HC-S plants had high levels of EPSPS protein. Higher levels of EPSPS siRNA of 21-24 bp, which could be involved in RNAi silencing, were observed in the HC_S plants by northern blot. This was not confirmed in the RNA-seq analysis, indicating other mechanisms might also be involved. A transcriptome analysis was done by mapping the reads to the reference transcriptome and running DESeq (Differential Expression Sequencing, R package). A short list of chloroplast transporters, transcription factors, and protein import machinery genes with at least 2 fold change in FPKM (Fragments Per Kilobase of transcript per Million mapped reads) between HC_R and HC_S were identified, which are worthy of further validation by qRT-PCR. We also proposed a hypothetical model to help illustrate the “real” GR mechanism which is essentially endowed by maintaining high levels of EPSPS protein in excess of the amount of glyphosate in the chloroplast. The basis of the model is that with a 270-fold difference in molecular weight increased EPSPS protein becomes limiting and so reducing glyphosate in the chloroplast could play a critical role in the success of the ‘extra’ EPSPS.

MOLECULAR SCREENING OF PPO AND GLYPHOSATE RESISTANCE IN PALMER AMARANTH POPULATIONS FROM SOUTHWEST NEBRASKA. Gustavo Vieira*1, Maxwel C. Oliveira2, Darci Giacomini3, Nikola Arsenijevic1, Patrick Tranel3, Rodrigo Werle4; 1University of Nebraska-Lincoln, North Platte, NE, 2University of Nebraska-Lincoln, Concord, NE, 3University of Illinois, Urbana, IL, 4University of Nebraska-Lincoln, Lincoln, NE (41)

Palmer amaranth (Amaranthus palmeri) is becoming a major threat to row crop production across the US. It has a late and extended emergence pattern and vigorous growth, which make control with POST-emergence herbicides difficult. Producers in southwest Nebraska have observed that their POST herbicide applications, which include glyphosate and/or PPO inhibitors, are no longer providing adequate levels of Palmer amaranth control, even when made when weeds are small (<10 cm). Glyphosate resistance in Palmer amaranth has been well documented in Nebraska but PPO resistance has not. Thus, the objective of this study was to evaluate the incidence of glyphosate and PPO resistance in Palmer amaranth populations of southwest Nebraska. In August of 2017, Palmer amaranth leaf samples (five plants site-1) were collected from 51 infested fields (including corn, soybeans, grain sorghum, and fallow) across 10 counties in southwest Nebraska. Genomic DNA was extracted from three samples per population and samples were tested for the presence of the PPO glycine 210 deletion (ΔG210), which is known to confer resistance to PPO herbicides in Palmer amaranth. Samples were also tested for genomic copy numbers of the EPSPS gene (an increase in genomic copy number of EPSPS is known to confer glyphosate resistance in Palmer amaranth). According to the molecular results, 59% of the populations had at least one sample positive for resistance to PPO-inhibiting herbicides. Forty-seven percent tested positive for resistance to glyphosate. Moreover, 27% of the populations tested positive for resistance to both herbicide groups. These results indicate that a significant percentage of Palmer amaranth populations in southwestern Nebraska are resistant to either or both glyphosate and PPO-inhibiting herbicides. Therefore, producers are encouraged to incorporate multiple effective herbicide modes of action with residual soil activity and adopt integrated weed management strategies for sustainable management of this troublesome weed species.

ADAPTING A MEDIA-BASED ROOT INHIBITION ASSAY TO INVESTIGATE DIFFERENCES IN AUXIN HERBICIDE RESPONSE IN HORSEWEED. Cara L. McCauley*, Bryan G. Young; Purdue University, West Lafayette, IN (42)

Rapid molecular assays are an important tool in weed science, particularly for confirming herbicide resistance in weed species in which the mechanism of resistance is well documented such as gene copy number or a target-site mutation. These assays fall short when the mechanism is unknown or a new resistance mechanism is suspected. While whole-plant dose-response assays continue to be the gold standard, greenhouse availability and personnel time are major limiting factors that affect the feasibility of conducting these experiments. The objective of this research was to develop a media-based root inhibition assay for use as a simplified dose-response experiment to investigate auxin herbicide response in horseweed. This assay provides a simplified method to compare a putative-resistant biotype to a known susceptible or to investigate relative plant response to herbicides within a mode of action. Sterile six-well polystyrene microplates were prepared with a medium containing 1X Murashige and Skoog basal growth medium supplemented with 0.4% agar and 0.8% sucrose. Echo® 720 fungicide was included at 500 ppm to control bleach-resistant endophytic contamination from the field-collected seed. Technical grade 2,4-D, dicamba, and halauxifen-methyl were dissolved in dimethyl sulfoxide and diluted in separate plates at nine concentrations ranging from 0.0001 to 1 µM. Horseweed seeds were surface-sterilized in 30% commercial bleach with 0.005% nonionic detergent and rinsed four times with sterile water. Seeds were spread onto solidified agar plates and incubated for 14 d at 25 C under continuous fluorescent lighting in a growth chamber. Individual seedlings were removed from the media with tweezers for root length measurement. The experiment included six replications and was repeated twice temporally. Data were analyzed using the three-parameter Weibull model with R software and the DRC package, a similar data analysis method that is utilized in greenhouse dose-response experiments. The calculated GR50 values were used for relative comparison among herbicides and were comparable to those generated from a whole-plant dose-response experiment conducted with the same horseweed biotypes and herbicide active ingredients. Results from this experiment provide proof of concept and methods for a media-based root-inhibition assay in auxin herbicide research.

CYTOCHROME P450-MEDIATED METABOLISM OF MESOTRIONE AND TEMBOTRIONE IN HPPD-INHIBITOR-TOLERANT SORGHUM. Balaji Aravindhan Pandian*, Amaranatha R. Vennapusa, Curtis R Thompson, Vara Prasad PV, Mithila Jugulam; Kansas State University, Manhattan, KS (43)

Post-emergent grass weed control continues to be a great challenge in grain sorghum, primarily due to its lack of herbicide options, unlike corn. 4- hydroxyphenylpyruvate dioxygenase (HPPD) inhibitors (e.g. mesotrione or tembotrione) are registered for use in corn to effectively manage broad-spectrum of weeds including grass weeds, but not in sorghum due to crop injury. Corn is known to metabolize these herbicides via cytochrome P450 activity. Our ongoing research recently identified four HPPD-inhibitor-tolerant sorghum genotypes (from a diversity panel), two each to mesotrione (#1 and #10) and tembotrione (#200 and #350); however, the basis for this tolerance is unknown. This research was conducted based on the hypothesis that the tolerant genotypes may rapidly metabolize mesotrione or tembotrione via P450 enzyme activity. Using the above four tolerant genotypes, along with a known susceptible (S#1) genotype of sorghum as well as a corn inbred (B73), experiments were conducted with cytochrome P450-inhibitors such as malathion or piperonyl butoxide (PBO) to determine the activity of cytochrome P450s in herbicide detoxification. Malathion at 2000, 4000 or PBO at 4500 g ai ha-1 was applied separately on sorghum genotypes (4-5 leaf-stage) 30 min prior to mesotrione or tembotrione application. Additionally, soil drenching of five mM malathion 48 hr after treatment was also given. Subsequently, the sorghum genotypes were treated with 1X, 2X or 4X of mesotrione (1X = 105 g ai ha-1) or 1X, 2X or 4X tembotrione (1X = 92 g ai ha-1). The results of this study found a reduction in biomass accumulation in both sorghum and corn plants that were pre-treated with either malathion or PBO, suggesting the P450 enzyme activity in detoxification of mesotrione or tembotrione is significant. Future research will also characterize the specific P450 enzymes involved in the detoxification of mesotrione or tembotrione in these sorghum genotypes.

HORSEWEED CONTROL: FALL VERSUS SPRING HERBICIDE APPLICATION TIMING. Josh Wehrbein*1, Lowell Sandell2, Christopher Proctor1; 1University of Nebraska-Lincoln, Lincoln, NE, 2Valent, Lincoln, NE (44)

Glyphosate-resistant horseweed (Conyza canadensis) is a difficult to manage weed for many corn and soybean producers in Nebraska and throughout the Midwest US. Timely herbicide application in the spring is often a challenge for many producers due to potentially unfavorable weather conditions or labor restrictions. In addition, horseweed primarily emerges in the fall as a winter annual in Nebraska, making fall herbicide control a potentially favorable option. The primary research objective was to evaluate the effect of fall compared to spring herbicide application timing on glyphosate-resistant horseweed control using several residual and postemergence (POST) herbicides. To address this, research studies were conducted over two years (2015/16 and 2016/17) at the Havelock research farm near Lincoln, Nebraska. Results from the first-year study indicate that residual herbicide treatments alone resulted in less than 90% control in early spring (0 days after spring treatment DAST). At the time of typical soybean planting (29 DAST) there was little difference between fall and spring applied treatments, but all burndown treatments provided >90% control. Late spring evaluation (52 DAST) showed four of the five residual plus POST treatments had higher control for fall compared to spring application. Similarly, results from year two of the study resulted in >90% control in early spring (37 days before spring treatment DBST) for all but four treatments. At late evaluation (73 DAST), as soybean would typically approach canopy closure, treatments resulted in less horseweed biomass than the control and few differences between fall and spring treatments. In addition, spring-applied treatments containing dicamba were among the treatments with the lowest horseweed biomass. These results indicate that fall herbicide applications have the potential to provide excellent (>90%) horseweed control up through soybean planting.

DIGITAL BOOKS FOR WEED SCIENCE - NOW COOKING WITH WEEDS. Bruce Ackley*, Alyssa Lamb; The Ohio State University, Columbus, OH (45)

Plant identification can be challenging and even intimidating for the inexperienced, but you don't need to identify every weed in the field to be a good crop producer. However, as a good producer, you should be able to identify the major weeds that are important to your operation and goals. At first glance, learning how to identify weeds can seem like a daunting task given the number and diversity of species, but it is not as difficult as it may seem. Generally, there is a specific group of weeds that tend to dominate disturbed habitats within any native landscape. Books were created to help people better understand the nature of the weeds they are trying to control, and plant identification is a key component of that understanding. These digital books provide a new way to use an old tool, visualization, in the world of weed science.

DEMONSTRATING HERBICIDE PROGRAMS IN CURRENT AND FUTURE SOYBEAN TECHNOLOGIES. Joe Ikley*1, Bill Johnson2, Bryan G. Young1; 1Purdue University, West Lafayette, IN, 2Purdue University, W Lafayette, IN (46)

There are many areas in the eastern Corn Belt that have weeds that are resistant to glyphosate, ALS-inhibiting herbicides, and PPO-inhibiting herbicides. This leaves soybean growers who plant Roundup Ready 2 Yield (RR2Y) soybean cultivars with very few to no in-season postemergence (POST) control options. With increasing adoption of LibertyLink (LL) soybean, and the subsequent launch of Roundup Ready 2 Xtend (RR2X) soybean, the objective was to demonstrate different programs available to manage tough-to-control weeds for growers across the state of Indiana. Treatments of different management intensities on RR2Y, RR2X and LL soybean were applied at five different sites around the state. These were single-replicate strip demonstrations placed at sites with different weed infestations, soil types, and climates. The treatments consisted of various combinations of herbicides applied early POST only, early POST followed by late POST, and preemergence (PRE) followed by POST with or without an additional residual herbicide. At various field days through the summer, around 1,300 clientele walked through the plots to observe how these technologies control waterhemp, giant ragweed, horseweed, and other common species found across Indiana. The demonstrations exhibited some inherit strengths and weaknesses of current and future soybean technologies. Treatments in RR2Y still worked on most weeds except those that were glyphosate-resistant. Additional residuals in the POST treatment were necessary for weeds with long germination windows such as waterhemp. Treatments in LL were excellent on most broadleaf weeds, including glyphosate-resistant weeds, but were weak on common lambsquarters and grasses. Treatments in RR2X provided excellent control of giant ragweed and glyphosate-resistant species, but provided marginal control of common lambsquarters, and poor control on velvetleaf. Overall, this was an effective educational tool to demonstrate different weed control programs in soybean and to engage in dialogue about new technologies with clientele across the state and will be repeated in 2018.

AN OVERVIEW OF HERBICIDE-RESISTANT WEEDS IN KANSAS. Vipan Kumar*1, Prashant Jha2, Phillip Stahlman1, Mithila Jugulam3, Randall S Currie4, J. Anita Dille3, Dallas E. Peterson3, Curtis R Thompson3, Douglas E Shoup5; 1Kansas State University, Hays, KS, 2Montana State University, Huntley, MT, 3Kansas State University, Manhattan, KS, 4Kansas State University, Garden City, KS, 5Kansas State University, Chanute, KS (47)

Herbicide-resistant (HR) weeds are a significant management concern among growers in the US Great Plains, including Kansas. Until now, fifteen weed species (3 monocots and 12 dicots) have evolved resistance to one or more herbicides, with 26 unique cases (species × site of action) of HR weed biotypes reported in Kansas. Among the reported HR weeds, about 50% are resistant to acetolactate synthase (ALS)-inhibiting herbicides and are particularly problematic in winter wheat, corn, sorghum, soybean, and alfalfa. The first case of herbicide resistance in Kansas was reported in kochia biotypes with resistance to photosystem II (PS II)-inhibitors (atrazine), which were found in corn fields and along railroads in 1976. Since then, biotypes of four weed species, including kochia, Palmer amaranth, tall waterhemp, and redroot pigweed, have been identified with resistance to PS II inhibitors. Out of 15 HR weed species in Kansas, six are resistant to glyphosate so far. A majority of those glyphosate-resistant (GR) weed species are found in fallow fields and GR cropping systems, including cotton, corn, and soybean. Horseweed was the first GR weed species reported in 2005 in Kansas and occurs throughout the state. Palmer amaranth, tall waterhemp, and kochia are the other three most important GR weed species in Kansas, mainly due to their widespread infestations. In fact, these three weed species have also evolved resistance to multiple herbicide sites of action. The first case of a kochia biotype with multiple resistance to four herbicide sites of action was found in Kansas corn fields, having resistance to ALS inhibitors (chlorsulfuron), PS II inhibitors (atrazine), synthetic auxins (dicamba), and glyphosate. Similarly, a Palmer amaranth biotype is resistant to hydroxyphenylpyruvate dioxygenase (HPPD)-, PS II-, and ALS-inhibitors in Kansas. The escalated reports on occurrence of multiple-herbicide resistance in weed species combined with the lack of any new herbicide mode of action being introduced within the last 30 years threaten the productivity, sustainability, and profitability of Kansas's cropping systems.

The on-going basic and applied research inquiries on HR weeds in the US Great Plains, including the understanding of genetic and molecular mechanisms, growth and reproductive fitness, and evaluation of alternative weed control systems (new HR crops, cultural, mechanical, cover crops, precision ag tools) will have direct implications towards the development of ecologically-based IPM programs for managing HR weeds in Kansas's cropping systems.

2017 EPA TOUR OF WESTERN KANSAS. Dallas E. Peterson*1, Phillip Stahlman2, Curtis R Thompson1, J. Anita Dille1, Mithila Jugulam1, Randall S Currie3, Michael Barrett4, Jill Schroeder5, Lee Van Wychen6; 1Kansas State University, Manhattan, KS, 2Kansas State University, Hays, KS, 3Kansas State University, Garden City, KS, 4University of Kentucky, Lexington, KY, 5USDA Office of Pest Management Policy, Washington, DC, 6WSSA, Alexandria, VA (48)

Since 2009, the Weed Science Society of America (WSSA) has co-sponsored a number of educational tours for EPA staff. The tours have provided a firsthand learning experience on a wide range of weed management issues, including herbicide resistance, aquatic use permits, pollinator protection, and application technologies in crop and non-crop areas that impact herbicide registrations and use guidelines. A hallmark of these tours has been the opportunity for direct dialogue between EPA personnel and growers, applicators, crop consultants, land and water managers, food processors, equipment manufacturers, and university research and extension employees. Previous tours have included stops in FL, NM, MO, IL, AR, MD, DE, and IA. In August 2017, a three-day tour in western Kansas was organized by Phillip Stahlman, Kansas State University and Michael Barrett, WSSA-EPA Liaison. The arid High Plains region of the US poses a unique set of challenges for weed management. Fourteen EPA staff from the Office of Pesticide Programs participated in the tour, which was hosted by Kansas State University with support from WSSA and several commodity organizations. The goals of the tour were to: 1) help EPA staff better understand dryland cropping systems and the difficulties of managing herbicide-resistant weeds in rainfall-limited environments; 2) provide EPA staff an opportunity to visit with local farmers, crop advisors, and applicators about the regulatory process and the practicality of different application requirements; and 3) allow farmers and crop advisors to provide feedback on the tools they need to successfully manage herbicide-resistant weeds. Some of the key points raised by farmers and applicators included: 1) the most problematic weeds in the High Plains regions include Palmer amaranth (Amaranthus palmeri), kochia (Kochia scoparia), horseweed (Conyza canadensis), and tumble windmillgrass (Chloris verticillata); 2) herbicide-resistant weeds are threatening the continued use of no-till cropping systems, which are critical for soil and water conservation, soil structure, soil health, crop yields, yield stability, and profitability; 3) continued availability of atrazine, dicamba, 2,4-D, and paraquat are important to help manage weeds in dryland cropping systems; 4) barriers to develop and register new herbicide sites of action need to be minimized; 5) avoid application requirements that are impractical and consider differences between geographies and different production systems; and 6) solicit input from practitioners regarding critical registration and application requirement decisions.

VISUALIZATION OF THE PENETRATION AND UPTAKE OF MULTIPLE ADJUVANT SYSTEMS USING CONFOCAL MICROSCOPY. Savana M. Lipps*1, Gregory K. Dahl2, Joe V. Gednalske2, Raymond L. Pigati3; 1University of Wisconsin-Madison, Madison, WI, 2Winfield United, River Falls, WI, 3WinField United, Shoreview, MN (49)

Herbicides often benefit from the addition of an adjuvant to improve uptake and penetration into the leaf. Visually analyzing which adjuvants can improve herbicide uptake and penetration at the cellular level can be challenging. The viability of using confocal microscopy to determine an adjuvant's ability to increase the foliar uptake and penetration of an herbicide was evaluated with water conditioner and crop oil concentrate adjuvants. Water conditioners and oils were mixed with water at labeled use rates and a fluorescent dye. One 10 microliter droplet was placed on a Chenopodium album L. leaf and Amaranthus rudis leaf for the water conditioner and crop oil evaluation, respectively to simulate an herbicide application. After a predetermined amount of time, the droplet was washed off the leaves and evaluated for fluorescence dye penetration depth and uptake intensity using a Nikon A1 Spectral Confocal microscope. Images were then evaluated with FIJI software. Images showed differences in the depth and intensity of the fluorescent dye for both the water conditioner and crop oil concentrate adjuvants. This confirms that confocal microscopy can be used as a method to evaluate an adjuvant ability to improve uptake and penetration of an herbicide and there are differences between adjuvants within both water conditioner and crop oil concentrate adjuvant classes.

IMPACT OF NOZZLE SELECTION ON POST APPLICATIONS OF HPPD-INHIBITING HERBICIDES. Vinicius Velho*1, Jeffrey Golus1, Kasey Schroeder1, Greg R Kruger2; 1University of Nebraska-Lincoln, North Platte, NE, 2University of Nebraska, North Platte, NE (50)

Nozzles play an important role on spray application systems. Application efficacy can be influenced by nozzle selection. Nozzles produce sprays with different droplet sizes, velocities and trajectories. HPPD-inhibiting herbicides causes bleaching symptoms on new growth by indirectly inhibiting carotenoid biosynthesis due to the requirement of plastoquinone as cofactor of phytoene desaturase. The objective of this study was to determine the impact of nozzle selection on postemergence applications of mesotrione. This study evaluated the influence of nineteen nozzles in three different weed species: Velvetleaf (Abutilon theophrasti Medik.), witchgrass (Panicum capillare L.), and prostrate pigweed (Amaranthus albus L.). Mesotrione at 53g a.i ha-1. The field study was conducted as completely randomize design (CRD). Visual estimations of injury were recorded on a scale of 0 to 100 with zero being uninjured plants and 100 being dead plants. These ratings were subjected to ANOVA using Statistical Analysis System (SAS). Droplet size was measured at the Pesticide Application Technology Laboratory at UNL-WCREC in North Platte, NE using a low-speed wind tunnel and a laser diffraction system. Each nozzle was traversed through the laser beam three separate times to measure the entire spray plume providing three repetitions. The nozzle was located 30 cm from the laser beam. Data were subjected ANOVA and means were separated using Fisher's Protected LSD test at α=0.05. The results show that all the nozzles provided effective broadleaf weed control, and as expected the grasses were not well controlled with mesotrione. The nozzle had little bearing on the effectiveness of mesotrione. It's important to emphasize that the AIXR nozzle was always among the bottom three nozzles and the 3D was the best for control of velvetleaf and prostrate pigweed but was not effective on grasses.

IMPACT OF NOZZLE SELECTION AND TANK-MIXTURE ON WEED EFFICACY. Debora O. Latorre*1, Dan Reynolds2, Bryan G. Young3, Jason Norsworthy4, Stanley Culpepper5, Kevin Bradley6, Ryan Rector7, Wayne Keeling8, David Nicolai9, Mandy Bish6, Greg R Kruger10; 1University of Nebraska-Lincoln, North Platte, NE, 2Mississippi State University, Starkville, MS, 3Purdue University, West Lafayette, IN, 4University of Arkansas, Fayetteville, AR, 5University of Georgia, Titon, GA, 6University of Missouri, Columbia, MO, 7Monsanto Company, St. Charles, MO, 8Texas A&M, Lubbock, TX, 9University of Minnesota, Farmington, MN, 10University of Nebraska, North Platte, NE (51)

Nozzle type plays an important role in herbicide performance on weed efficacy. Applicators must continuously manage the interactions between application volume, nozzle flow rate, nozzle type, operating pressure, travel speed, and nozzle spacing while considering droplet size, drift and herbicide efficacy. Nozzles have been designed to produce large spray droplets without changing the spray volume. Additionally, some adjuvants added to the herbicide solution can increase droplet size and reduce drift beyond the nozzle design chosen for a particular application. Relying solely on enlarging the droplet size decreases coverage and potentially reduces weed control. The objective of this study was to identify a nozzle by tank-mixture combination that optimizes weed control in dicamba-tolerant crops. Field studies were conducted as a randomized complete block design with a factorial arrangement of treatments and with four replications at eight different states: Arkansas, Georgia, Kansas, Indiana, Mississippi, Missouri, Nebraska and Texas. Dicamba was applied at 0.5 kg ae ha-1 alone and in tank-mixtures with glyphosate at 1.2 kg ae ha-1. Herbicide treatments were used alone and in combination with one of five adjuvants (polyacrylamide 1 at 0.5% v v-1, polyacrylamide 2 at 0.125% v v-1, guar gum 1 at 0.75% v v-1, guar gum 2 at 0.5% v v-1, or guar gum 3 at 0.5% v v-1). Solutions were prepared with PTSA fluorescent tracing dye at 0.6 g L-1. Each treatment was applied using 206 kPa at 6.4 kph, to provide a constant carrier volume of 94 L ha-1 using a CO2 backpack sprayer with four nozzles spaced 50 cm apart. The boom was held 50 cm above the plants, and the applications were made when the weeds were 10-15-cm tall. The treatments were applied using one of three venturi nozzles: TTI110015, TDXL-D110015, and ULD120015. Two petri dishes (one at the top and one at the bottom of crop canopy) were placed in every plot to determine deposition rate for each treatment. After plots were treated, visual estimations of injury were collected at 28 d after application. The petri dishes were processed and analyzed at the Pesticide Application Technology located in UNL-WCREC in North Platte, NE. The petri dishes were filled with 40 mL of the solvent (3875 mL of distillated water and 112 mL of 91% isopropyl alcohol), mixed for 15 sec, and 10 mL of the effluent was pipetted into a vial and analyzed using a spectrofluorimeter. Each nozzle was tested at the low-speed wind tunnel at the Pesticide Application Technology Lab using a Sympatec HELOS- ARIO/KR laser diffraction system for droplet measurements. Data showed that there was little difference between treatments in terms of deposition. Tank-mixtures with dicamba and guar gum 1 at 0.75% v v-1 increased the droplet size for the three nozzles. Treatments containing glyphosate showed more consistent control than the treatments with dicamba alone across adjuvants tested, particularly on monocotyledonous weeds. Nozzle and adjuvant had little effect on the control of problematic weeds across locations. Further testing is needed to better understand the impact of ultra-coarse nozzles coupled with drift reducing adjuvants will impact efficacy of other herbicides that may be used in tank mixtures with dicamba. For applications of dicamba or dicamba plus glyphosate tank-mixtures, the nozzle and adjuvant combinations should cause concern based on this study. However, in the context of other reported research the authors believe there is still a high risk for weed escapes. Should applicators see weed control failures, actions should be taken to increase coverage including but not limited to the increase in carrier volume and the use of legally approved surfactants, sticker/spreader adjuvants and other adjuvants which will increase coverage.

EFFECTS OF SOLUTION VISCOSITY ON HERBICIDE EFFICACY. Gabrielle C. Macedo*1, Glen Obear2, Frank Sexton3, Jeffrey Golus1, Kasey Schroeder1, Greg R Kruger4; 1University of Nebraska-Lincoln, North Platte, NE, 2University of Nebraska-Lincoln, Lincoln, NE, 3Exacto, Inc., Sharon, WI, 4University of Nebraska, North Platte, NE (52)

The application of herbicides is the primary weed control method and a successful application is dependent upon a good spray deposition on the target with a minimum loss to the environment. The addition of some adjuvants to the solution is intended to improve deposition and decrease herbicide drift. The objective of this study was to assess the combinations of herbicides with adjuvants in their influence at efficacy on treated plants. Two greenhouse studies were conducted as a completely randomized design with five replications at the UNL-WCREC in North Platte, NE. In the first study, the herbicide acifluorfen (12 g ai ha-1) was sprayed in mixture with four concentrations of an experimental adjuvant with unique physiochemical properties: 0, 0.2, 0.4 and 1% v v-1 on sorghum, oats, watermelon, commom lambsquarters, Palmer amaranth, common waterhemp and velvetleaf. In the second study, a dose-response curve was fitted with the data from dicamba at 0, 2, 4, 8, 16 and 32 g ae ha-1 sprayed in mixture with four concentrations of another experimental adjuvant at 0, 0.1, 0.5 and 1% v v-1 on commom lambsquarters and Palmer amaranth plants. Herbicide treatments were made when plants were 10 to 15 cm tall, with a carrier volume of 94 L ha-1, at 24 km hr-1, 434 kPa using ER11004 and DR11004 nozzles. Plants were sprayed in a 1.67 m x 4.2 m spray chamber with a three nozzle track sprayer. Nozzles were spaced 50 cm apart and plants were located 50 cm from the nozzles during application. After the treatment, visual estimations of herbicide injury were collected at 7, 14, 21, and 28 d after application (DAA). At 28 DAA, plants were clipped at the soil surface, to dried to a constant mass, and dry weights were recorded. In the first study, the dry weight data were subjected to ANOVA and means were separated using Fisher's Protected LSD test with the Tukey adjustment. For the second study, the dry weight data were analyzed using a nonlinear regression model with the drc package in R 3.4.2. The ER1004 nozzle provides Fine droplets while DR11004 nozzle provides Very Coarse droplets. For EXT876 + acifluorfen, the change in weed control depends on the weed species and the addition of EXT876 increases control for watermelon, common lambsquarters, oats and sorghum. For EXT1112 + dicamba, optimal control was found using 0.5% v v-1 of EXT1112 to Palmer amaranth while for common lambsquarters the best control was showed using 0.1% v v-1 of EXT1112. There are no difference between nozzles because similar results were found using fine (ER11004) or very coarse (DR11004) droplets. Additional research needed to understand the relation between coverage and control.

IMPACT OF DROPLET SIZE ON POST APPLICATIONS OF HPPD-INHIBITING HERBICIDES. Barbara Vukoja*1, Jeffrey Golus1, Kasey Schroeder1, Greg R Kruger2; 1University of Nebraska-Lincoln, North Platte, NE, 2University of Nebraska, North Platte, NE (53)

Spray droplet size is one of the most important parameters in pesticide application technology. By understanding the importance of spray droplet size, efficacy of application can be improved and off target movement minimized. The objective of this research was to determine the optimum spray droplet size for efficacy with HPPD-inhibiting herbicides. A greenhouse study was conducted at the UNL-WCREC in North Platte, NE on common lambsquarters (Chenopodium album L.), velvetleaf (Abutilon theophrasti Medik), Palmer amaranth (Amaranthus palmeri) and grain sorghum (Sorghum bicolor L.). HPPD-inhibiting herbicides (mesotrione and isoxaflutole) were applied separately at a rate of 0.105 kg ae ha-1. Each treatment was applied with a three-nozzle laboratory track sprayer with nozzles spaced 50 cm apart and plants located 50 cm below the nozzles during application. The non-venturi ER11002, MR110025, DR11003 and UR11004 were used in this study to provide a range of droplet sizes without significantly changing the nozzle design. Application pressures used were 262, 276, 345 and 448 kPa, respectively, matched with the speed treatment from 9.6 to 24 km hr-1 to deliver 94 L ha-1. Visual estimations of injury were collected 7, 14, 21 and 28 d after application (DAA). At 28 DAA, plants were clipped at the soil surface and fresh weights were recorded as well as dry weights after they have been dried to the constant mass. Furthermore, droplet size distributions were measured using a low-speed wind tunnel with laser diffraction. Data were analyzed using generalized additive models (GAM) to predict optimum droplet size for weed control. Results have shown that impact of droplet size accounted for less than 10% of variation in controlling weeds. Optimum droplet size for controlling velvetleaf, grain sorghum, and Palmer amaranth is classified as Ultra Coarse, which will provide better efficacy and less off-target movement. Common lambsquarters had a Fine spray quality as the optimum droplet size for control.

IMPACT OF DROPLET SIZE AND WEED SIZE ON HPPD-INHIBITING HERBICIDE EFFICACY. Thiago H. Vitti*1, Jeffrey Golus1, Kasey Schroeder1, Greg R Kruger2; 1University of Nebraska-Lincoln, North Platte, NE, 2University of Nebraska, North Platte, NE (54)

Droplet size is an important component influencing application efficacy, especially with contact herbicides. In general, contact herbicides need a good coverage on plants to be effective. Application timing is a key factor in chemical weed control, where plants at more advanced growth stages are generally more difficult to control. HPPD inhibitor herbicides affect plants new growth causing bleaching symptoms by indirectly inhibiting carotenoid synthesis. The objective of the study was to evaluate the efficacy of Callisto® (Mesotrione) and Balance PRO® (Isoxaflutole) using different nozzles on weeds at different development stages. A greenhouse study was conducted at the UNL-WCREC in North Platte, NE with three different plant species (grain sorghum, Sorghum bicolor (L.) Moencch subsp. Bicolor.; common lambsquarters, Chenopodium album L.; and Palmer amaranth, Amaranthus palmeri). Five different nozzles (ER11004, SR11004, MR11004, DR11004, and UR11004) were used at 40 psi and plants were sprayed using a 1.67 x 4.2 m track spray chamber with three nozzle boom spray. Applications were performed with the plants at three different growth stages (12.7, 25.4, and 38.1 cm). Visual injuries were rated for each plant 7, 14, 21 and 28 days after treatment (DAT) and on the 28th day plants were harvested, weighted and dried. Wet and dry weights were recorded. Droplet size measurements were recorded using a Sympatec HELOS-VARIO/KR laser diffraction system. Each nozzle was traversed through the laser beam three separate times to measure the entire spray plume providing three repetitions. Visual injury and droplet size data were subjected to ANOVA and means were separated using Fisher's Protected LSD test at α=0.05

WHEAT STUBBLE HEIGHT AND NOZZLE TYPE INFLUENCES SPRAY PENETRATION OF A DICAMBA AND GLYPHOSATE TANK MIXTURE. Luana M. Simao*1, Greg R Kruger2, Cody Creech1; 1University of Nebraska-Lincoln, Scottsbluff, NE, 2University of Nebraska, North Platte, NE (55)

No-till production provides increased soil water conservation and erosion control as well as reduced operational costs. The viability of this system depends on effective chemical weed control. The objective of this study was to evaluate the spray deposition of a glyphosate (2.24 kg ha-1) and dicamba (0.56 kg ha-1) tank mixture applied (140 L ha-1) in wheat residue with different stubble heights, nozzle types, and application direction of travel. The treatments consisted of three different heights (68, 35 and 0 cm) of wheat stubble, four nozzles types (AIXR, TTJ, TTI and XR), and three different spraying directions in relation to the wheat stubble rows (parallel, angular, and perpendicular). Collectors were placed on the ground between wheat stubble rows and situated between nozzles which were spaced 52 cm apart. The experiment was conducted as a split-split plot design in two wheat fields near Sidney, NE with four replications. The spray deposition of the AIXR nozzle was similar to the TTI and 13 and 21% greater than the TTJ and XR nozzles, respectively. Tall and medium wheat stubble reduced herbicide spray deposition relative to the no-stubble treatment in one field by 41 and 26%, respectively, and 28 and 13%, respectively, in the other field. Spray application direction of travel in a parallel or angular track to the wheat row increased the amount of herbicide deposition in one field 30 and 14%, respectively. The results of this study suggest that increasing amounts of wheat residue can reduce the amount of spray droplets that are able to reach targets near the soil surface. This can be overcome by using an AXIR nozzle and by not spraying perpendicular to the wheat rows.

INFLUENCE OF AGITATION SYSTEMS AND SITTING TIME ON DROPLET SIZE WITH XTENDIMAX, ROUNDUP XTEND, CLARITY AND ROUNDUP POWERMAX. Andre O. Rodrigues*1, Ulisses R. Antuniassi2, Cody Creech3, Bradley K. Fritz4, Greg R Kruger5; 1University of Nebraska-Lincoln, North Platte, NE, 2UNESP, Botucatu, Brazil, 3University of Nebraska-Lincoln, Scottsbluff, NE, 4ARS-USDA, College Station, TX, 5University of Nebraska, North Platte, NE (56)

Droplet size is a key component in mitigating particle drift as well as maximizing control. Formulations and tank-mixtures influence droplet size. Agitation systems are an important component of the spray application process. They ensure proper mixing of all components of a spray application and thus help optimum performance. Sitting time of solutions might be a factor also affecting pesticide applications. Growers can often leave a tank full of spray solution sit for a period of time because of rain prior to application. The objective of this study was to evaluate the influence that agitation systems with three different types of pumps (diaphragm, roller and centrifugal) combined with three tank shapes (rectangle cone bottom, square and cylinder shapes). We also evaluated sitting times for this study at 0, 12, 24, and 48 hr. Solution were re-circulated through the system for 25 cycles and then solutions were separated into groups by siting time. The solutions were ran in the low-speed wind tunnel at the proper time with a TTI1104 nozzle at 434 kPa. Solutions were prepared with 1,117 g ae ha-1 of Xtendimax, 1,120 g ae ha-1 of Clarity, 1,262 g ae ha-1 of Roundup Powermax, and 2,244 g ae ha-1 of glyphosate and 1,122 g ae ha-1 of dicamba of Roundup Xtend. Xtendimax and Clarity were tested alone and also in tank-mixtures with Roundup Powermax, and Roundup Xtend was tested alone. The study was conducted at the Pesticide Application Technology Laboratory at UNL-WCREC in North Platte NE, using a low-speed wind tunnel and droplet measurements were made using a laser diffraction system. The nozzle is located 30 cm from the laser beam. Each nozzle was traversed through the laser three separate times to measure the entire spray plume providing three repetitions. Among sitting times, 12 hours is the one providing greater droplet size except when solution is Roundup Xtend. Xtendimax averaged across pumps and sitting time the largest droplet size with 860 µm while Roundup Xtend had the smallest droplet size with an average of 760 µm.

EFFECTIVENESS OF HYPERSPECTRAL IMAGING TECHNOLOGY IN DETECTING HERBICIDE INJURY. Julie M. Young*1, Haozhen Nie2, William G. Johnson2, Jian Jin1, Bryan G. Young2; 1Purdue University, WEST LAFAYETTE, IN, 2Purdue University, West Lafayette, IN (57)

Hyperspectral imaging technologies have been investigated for differentiating between weed and crop species, identifying invasive weeds, and detecting crop stress due to weeds. There is a lack of information on the utility of hyperspectral imaging technology in detecting herbicide injury. The ability to detect, quantify, and differentiate herbicide injury in crops and weeds using reflective light measurements may prove to have useful applications in field and greenhouse settings. The objective of this research was to determine the effectiveness of hyperspectral imaging technology in detecting injury to soybean from dicamba and glyphosate in the greenhouse. Glufosinate-resistant, glyphosate-resistant and dicamba-resistant soybean at the V2 growth stage were treated with glyphosate (630 g ae ha-1), dicamba (280 g ae ha-1), or a combination of glyphosate plus dicamba. An untreated check was included for comparison. Soybean were imaged one d prior to herbicide application, two hr after application, and daily for the first seven d after application (DAA) with a hyperspectral imaging system with a spectral resolution of 0.6 nm and a range of 400 to 1020 nm. Visual evaluations of soybean injury, fresh weight, and dry weight were determined at seven DAA. The experiment included 12 replicates for each treatment and was repeated. Image processing technologies such as segmentation and morphological feature extraction were applied to the images and the plant canopy reflectance spectra were calculated and analyzed to track the spectral change after the different chemical treatments. Statistical plant feature prediction models were then applied to analyze the correlation between the spectra change and treatment over the time course after the spraying treatment. Hyperspectral imaging combined with statistical spectroscopy modeling/classification technologies such as Partial Least Squares was able to differentiate between untreated, glyphosate-treated, and dicamba-treated glufosinate-resistant soybean as early as two hr after application, before herbicide injury was visible to the human eye. From one to four DAA, image analysis was able to distinguish between treatment with dicamba and glyphosate on susceptible soybean and no herbicide treatment. These results also show the potential for recognizing both the type of herbicide and the time after treatment by spectral analysis.

POTENTIAL YIELD LOSS DUE TO WEEDS IN DRY BEANS IN CANADA AND THE UNITED STATES. Nader Soltani*1, J. Anita Dille2, Peter H Sikkema1; 1University of Guelph, Ridgetown, ON, 2Kansas State University, Manhattan, KS (58)

Earlier Weed Science Society of America (WSSA) Weed Loss Committee reports by Chandler et al. (1984) and Bridges (1992), provided a summary of crop yield losses throughout various North American regions if weeds were left uncontrolled. This manuscript is a report from the current WSSA Weed Loss Committee on potential crop yield losses due to weeds in dry bean based on data collected from various regions of the US and Canada. Dry bean yield loss estimates were made by comparing dry bean yield in the weedy control with plots that had >95% weed control from research studies conducted in dry bean growing regions of the US and Canada over a 10 yr period (2007 to 2016). Results from these field studies showed that dry bean growers in Idaho, Michigan, Montana, Nebraska, North Dakota, South Dakota, Wyoming, Ontario and Manitoba would potentially lose an average of 50, 31, 36, 59, 94, 31, 71, 56, and 71% of their dry bean yield which equates to a monetary loss of US$36, 40, 6, 56, 421, 2, 18, 44 and 44 million, respectively, if they use their best agronomic practices without any weed management tactics. Based on 2016 census data, at an average yield loss of 71.4% for North America, dry bean production in the US and Canada would be reduced by 941,000 and 184,000 MT out of their total production of 1,318,000 and 258,000 MT valued at approximately US$622 and US$100 million, respectively, to uncontrolled weeds. This study documents the dramatic yield and monetary losses in dry beans due to weed interference and the importance of continued funding for weed management research to minimize dry bean yield losses.

DRY BEAN, SUGARBEET, ALFALFA, AND CUCUMBER RESPONSE TO BICYCLOPYRONE RESIDUES. Daniel Wilkinson*1, Christy L. Sprague2; 1, DeWitt, MI, 2Michigan State University, East Lansing, MI (59)

Bicyclopyrone is one of the newest HPPD-inhibiting herbicides (Group 27) registered for use in corn. It is currently a component of several pre-mixtures. New uses could result in bicyclopyrone being applied alone in corn and other crops. Currently, there is very little data available on the carryover potential of bicyclopyrone. Based on this data gap a study was designed to: 1) evaluate the carryover potential of bicyclopyrone to two classes of dry edible beans, (kidney and black beans), sugarbeets, alfalfa, and cucumbers, and 2) compare the potential carryover effects from bicyclopyrone to mesotrione in these crops. Mesotrione currently has an 18 month rotation restriction for these crops. Field experiments were established in 2015 and 2016 at two locations: 1) East Lansing, MI on a loam soil with a pH of 6.0 and organic matter of 4.5% and 2) Richville, MI on a clay loam soil with a pH of 7.8 and organic matter 2.6%. The experiment was setup as a split plot design with four replications. The main plots were the herbicide treatments: bicyclopyrone applied at 50 and 100 g ai ha-1 (1X and 2X), mesotrione applied at 210 g ai ha-1, and a nontreated control. Treatments were applied in early June to V3 corn. The following springs, sugarbeets and alfalfa were planted in mid-April and cucumbers and dry edible beans were planted in mid-June. Minimum tillage with a shallow soil-finishing tool was done prior to planting. Stand counts were taken seven and 21 d after emergence and crops were evaluated bi-weekly for injury throughout the growing season and harvested. Regardless of herbicide treatment, there was very little injury and no yield response to dry beans, sugarbeets, and alfalfa from applications of bicyclopyrone or mesotrione compared with the control in 2016. In 2017 at East Lansing sugarbeets and kidney beans were both injured by mesotrione and the 2X rate of bicyclopyrone. Sugarbeets did not survive when planted after mesotrione. The 2X rate of bicyclopyrone caused approximately 35% sugarbeet injury, but did not affect yield. Injury to kidney beans from mesotrione and the 2X rate of bicyclopyrone was 35% and 15%, respectively, again yield was not affected. Greenhouse studies also confirmed that sugarbeets, dry beans, cucumbers, and alfalfa are less sensitive to bicyclopyrone than mesotrione and that sugarbeets were the most sensitive of these five crops. From this research it appears that a rotational restriction of 10 months for bicyclopyrone applications may be appropriate prior to planting alfalfa and 12 months for bicyclopyrone applications may be appropriate prior to planting dry beans and cucumbers. However, further research will be needed to refine the rotation restrictions for bicyclopyrone to sugarbeets.

PERFORMANCE OF FIELD PEA HERBICIDES IN WESTERN NEBRASKA. Samuel T. Koeshall*1, Rodrigo Werle1, Cody Creech2; 1University of Nebraska-Lincoln, Lincoln, NE, 2University of Nebraska-Lincoln, Scottsbluff, NE (60)

Yellow field peas (Pisum sativum) are highly competitive against weeds upon canopy yet require early season weed control to prevent yield loss. As a recently adopted crop in Nebraska, herbicide evaluations were needed to provide recommendations for producers for local scenarios. Trials were initiated in 2015 at the University of Nebraska-Lincoln High Plains Ag. Lab near Sidney, NE to evaluate the effects of application timing on weed control and pea yields of using a variety of herbicide treatments. Herbicide applications were made in the fall and early spring prior to planting, and post-emergence of the field pea cultivar DS Admiral. Visual estimations of control of a variety of weeds were recorded throughout the growing season. The plots were direct harvested using a small plot research combine, and grain yield was recorded for the fall applied herbicides. A sulfentrazone + s-metolachlor fall application provided adequate control of the weeds present and had the greatest yield although not different than the sulfentrazone + s-metolachlor spring treatment or the fall and spring applied sulfentrazone + carfentrazone treatment. Among the spring applied herbicides, imazethapyr provided less than adequate control of grass species and some broadleaves. This research demonstrated that fall applied herbicides can be just as effective at controlling weeds in field peas as spring applied herbicides. Also, that any number of herbicides can be used in the spring to achieve adequate results. Fall applications can alleviate some of the labor and time constraints that are common for producers in the spring.

SAFFLOWER VARIETY SUSCEPTIBILITY TO SULFENTRAZONE INJURY. Clair L. Keene*1, Caleb Dalley2; 1North Dakota State University, Williston, ND, 2North Dakota State University, Hettinger, ND (61)

Safflower is an oil seed crop well adapted to the semi-arid conditions of western North Dakota. Growing safflower in this region can increase water use efficiency and reduce disease pressure in small grain rotations. Despite these benefits, safflower production is limited by a lack of herbicides that control broadleaf weeds while exhibiting consistent crop safety. To determine the suitability of sulfentrazone as a pre-emergence herbicide for safflower, we conducted experiments using five safflower varieties and three sulfentrazone rates at two locations in western North Dakota in 2016 and 2017. A factorial design with four replications arranged in a randomized complete block was used. Safflower varieties included Cardinal, MonDak, NutraSaff, Hybrid 9049, and Hybrid 1601; sulfentrazone rates of 0.07, 0.12, and 0.18 kg ha-1 were compared with a weed free control. The weed free control was treated PRE with 2.15 kg ha-1 s-metolachlor and maintained with hand-weeding. At Williston in 2016, substantial injury was observed at three and five wk after emergence (WAE), with Hybrid 1601 exhibiting the greatest injury and Cardinal the least. At Hettinger in 2016, Hybrid 1601 exhibited the highest injury at two and four WAE while varieties Cardinal and NutraSaff showed the least injury. Yield at Williston in 2016 was influenced by variety and herbicide treatment. Weed free safflower yielded 1,947 kg ha-1, which was greater than safflower treated with sulfentrazone (1510-1563 kg ha-1), regardless of rate. At Hettinger, safflower yield averaged 2,399 kg ha-1 and there were no differences among herbicide treatments. In 2017, western North Dakota experienced an extreme drought, with Williston and Hettinger receiving less than three cm of rain between planting and late July. Herbicide activation was limited and safflower injury ratings were lower at Williston in 2017 than in 2016. Dry conditions interfered with safflower emergence at Hettinger and no data were collected. At Williston, Hybrid 1601, Hybrid 9049, and MonDak exhibited comparable levels of injury at four and six WAE. Despite differences in injury symptoms, there were no differences in yield among herbicide treatment in 2017, only among varieties. Drought reduced yields by one-half to two-thirds of 2016 yields. Results suggest that Hybrid 1601 and 9049 are more susceptible to sulfentrazone injury than the other varieties tested, but that early-season injury symptoms do not necessarily result in yield loss. Additionally, if sulfentrazone is needed to control troublesome weeds, selecting Cardinal or NutraSaff may reduce risk of injury.

RESPONSE OF WHITE AND YELLOW POPCORN HYBRIDS TO GLYPHOSATE, ENLIST DUO, OR XTENDIMAX. Ethann R. Barnes*1, Nevin C. Lawrence2, Stevan Z. Knezevic3, Amit Jhala1; 1University of Nebraska-Lincoln, Lincoln, NE, 2University of Nebraska-Lincoln, Scottsbluff, NE, 3University of Nebraska-Lincoln, Concord, NE (62)

Volatilization, drift, and tank contamination risk of glyphosate + 2,4-D, glyphosate, and dicamba to popcorn production has not been assessed. A field experiment was conducted at the University of Nebraska—Lincoln, South Central Agricultural Lab near Clay Center, NE in 2017 to determine the effects of glyphosate + 2,4-D, glyphosate, or dicamba on the injury, above ground biomass, and yield of yellow and white popcorn. Treatments included weed-free control, untreated control, and four rates of Enlist DUO (0.25X, 0.125X, 0.063X, and 0.031X), glyphosate (0.25X, 0.125X, 0.063X, and 0.031X), or XtendiMax (2X, 1X, 0.5X, and 0.25X) applied POST at V5 or V8 popcorn growth stages. Visual estimates of herbicide injury, plant above ground biomass, and yield were collected. Four parameter log-logistic models were fit to each herbicide and model parameters and ED5 (effective dose required to result in 5% injury) were compared. Models were combined when parameters didn’t vary across hybrids (white or yellow) or herbicide application timings (V5 or V8). The ED5 for glyphosate injury was 38.6 g ae ha−1 regardless of growth stage or hybrid. Glyphosate biomass reduction and yield loss ED5 were 0.00000007 and 0.0008 g ae ha−1, respectively, at V5 stage growth stage. At V8 stage, glyphosate biomass and yield loss ED5 were and 97.5 and 33.0 g ae ha−1, respectively. Glypohsate + 2,4-D ED5 at the V5 stage were 4.6 and 3.7 g ae ha−1 regardless of hybrid for popcorn injury and biomass reduction, respectively. At the V8 stage, glyphosate + 2,4-D injury and biomass reduction resulted in ED5 of 16.3 and 4.8; and 50.8 and 0.1 g ae ha−1 for the yellow and white popcorn hybrid, respectively. A late application of glyphosate + 2,4-D resulted in a yield loss ED5 of 11.56 g ae ha−1. Dicamba applied at V5 resulted in ED5 of 84.5 and 2.2 g ae ha−1 for yellow and white hybrids, respectively. At V8, dicamba resulted in ED5 of 906.5 g ae ha−1 regardless of hybrid. Dicamba did not result greater than 5% yield losses or biomass reduction, but did result in substantial brace root malformation. Results from the first year of this study suggest that both hybrids were equally sensitive to glyphosate, but the yellow hybrid was less sensitive to glyphosate + 2,4-D and dicamba. Application at V5 resulted in more injury and higher biomass and yield reduction than the V8 application.

GRAIN SORGHUM RESPONSE TO POST PYRASULFOTOLE AND BROMOXYNIL PREVIOUSLY TREATED WITH PRE HERBICIDES CONTAINING MESOTRIONE. Seth Menzer, Curtis R Thompson*, Mithila Jugulam; Kansas State University, Manhattan, KS (63)

Grain sorghum is one of the most important grain crops worldwide, and the US leads the world in sorghum production. Weed control is the single greatest challenge facing sorghum growers, in part because of few postemergence (POST) herbicide modes of action are registered for the crop. Pyrasulfotole + bromoxynil is a commercial pre-mixture of a 4-hydroxyphenyl pyruvate dioxygenase (HPPD)-inhibitor and a photosystem II (PS II)-inhibitor used for broadleaf weed control in sorghum. However, the label warns that unacceptable crop injury may occur if applied to sorghum previously treated with a preemergence (PRE) product containing mesotrione, also a HPPD inhibitor. The objective of this research was to determine whether crop injury from pyrasulfotole + bromoxynil following PRE applications with mesotrione resulted in greater injury and yield loss than when applied following PRE products without mesotrione. Three field experiments were conducted spanning two years and two locations. Severe injury was observed three and seven d after treatment when PRE applications with mesotrione were followed by pyrasulfotole + bromoxynil POST. However, this treatment was seldom greater than when pyrasulfotole + bromoxynil was applied following PREs without mesotrione. No injury was observed at 28 DAT for any herbicide treatments in any site-year, and no decrease in final grain yield was observed. PRE treatments containing mesotrione followed by pyrasulfotole + bromoxynil did not result in unacceptable crop injury and provided excellent season-long control of broadleaf weeds when PREs were activated and thus is an effective herbicide regimen for producers concerned about broadleaf weed control in grain sorghum.

GROWTH AND REPRODUCTIVE RESPONSE OF MISSOURI GRAPES TO DICAMBA. Sarah E. Dixon*1, Reid Smeda2; 1Graduate Research Assistant, Columbia, MO, 2University of Missouri, Columbia, MO (64)

Widespread adoption of dicamba-tolerant soybeans will increase the exposure of sensitive crops such as grapes to dicamba, where off-target movement may occur via particle or vapor drift. In 2017 in Missouri, the objective of this field research project was to determine the growth and reproductive impact of dicamba on grape from both particle and vapor drift. Established grapes (Vidal) were exposed to low rates of dicamba, delivered as a spray solution (36 or 72 ppm) or vapor during grape flowering and early fruit set. Throughout the growing season, plant injury and shoot length were recorded for selected shoots. At harvest, grape yield and cluster weight were recorded. Based on observations, grapes appeared more sensitive to dicamba exposure during flowering than early fruit set. Injury symptoms (leaf cupping and feathering) were observed on grape shoots for both rates of particle and vapor drift of dicamba at both application timings. Injury at the end of the season was estimated to be 65-67% for particle drift; injury was 39 and 51% for plants exposed to vapor drift. Over the course of the growing season, shoot growth was reduced by 80 and 76% when flowering grapes were exposed to dicamba via particle drift at 36 and 72 ppm, respectively. Grape yield for plants exposed at flowering was reduced up to 26 and 53% for particle and vapor drift treatments, respectively. Grapes are highly sensitive to dicamba at low rates in the form of both particle and vapor drift, with flowering plants more sensitive than plants at early fruit set. Future research will focus on residual effects in grape yield the following year.

SENSITIVITY OF IRRIGATED GRAPES TO MICRO-RATES OF CLARITY, ENGENIA, AND XTENDIMAX. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (65)

A study was conducted in summer 2017 at Haskell Ag Lab, Concord, NE to evaluate the sensitivity of grapes to different micro-rates of dicamba formulations (Clarity, Engenia, and Xtendimax). Pot-grown “Frontenac” variety (four plants × four replicates) were sprayed with micro-rates of Clarity, Engenia, and XtendiMax at 0, 1/10, 1/50, 1/100, 1/500, and 1/1000 of the label rate (560 g ae ha-1) in a randomized complete block design. Visual estimations of injury were collected at 7, 14, 21 and 28 d after treatment (DAT). Maximum accumulated vine length of grape was collected at 14 and 21 DAT. Micro-rates of the three evaluated products had effects on growth of grapes. A dose range of 6.54 to 9.13 g ae ha-1 caused 50% injury at 21 DAT depending on the dicamba formulation. A dose range of 1.83 to 7.58 g ae ha-1 caused 50% (~49 cm) reduction in vine length at 21 DAT depending on the dicamba formulation. The grapes were consistently more sensitive to XtendiMax than Clarity and Engenia. For instance, a dose of 1.83 g ae ha-1 of XtendiMax was required to cause 50% reduction in vine length compared to 5.64 and 7.59 g ae ha-1 required in Clarity and Engenia respectively. In general, these results suggests that grape is sensitive to low rates of dicamba. Hence, off-target movement of dicamba to grape should be prevented.

SENSITIVITY OF IRRIGATED TOMATO TO MICRO-RATES OF CLARITY, ENGENIA, AND XTENDIMAX. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (66)

There is a concern that the widespread use of dicamba in dicamba-tolerant (DT) soybeans can result in un-intended drift due to windy conditions in Nebraska (and elsewhere). Therefore, the objective, of this study was to evaluate the sensitivity of pot-grown tomato to different micro-rates of dicamba formulations (Clarity, Engenia and XtendiMax). Our study was conducted in 2017 at Haskell Ag Lab, Concord, NE. Sixteen pot-grown tomato (early-bird variety) were treated with 6 micro-rates (0, 1/10, 1/50, 1/100, 1/500, and 1/1000 of the label rate (560 g ae ha-1)) of Clarity, Engenia, and XtendiMax in a randomized complete block design with four replicates. Visual estimation of injury was collected at 7, 14, 21 and 28 d after treatment (DAT). Plant heights were collected at 14 and 21 DAT. All three dicamba formulations negatively impacted tomato growth at about the same level (no significant differences). A dose range of 3.98 to 5.35 g ae ha-1 caused 50% injury at 21 DAT. A dose range of 5.01 to 9.76 g ae ha-1 caused 50% (~24 cm) reduction in plant height at 21 DAT depending on the dicamba formulation. For example, an Engenia dose of 3.98 g ae ha-1 reduced plant height by 50% compared to 4.49 and 5.35 g ae ha-1 of XtendiMax and Clarity, respectively. However, these values were not statistically different as indicated by their standard errors. These results suggested that the proper application procedures should be followed to avoid dicamba drift on tomato.

EVALUATION OF A NEW HERBICIDE, SWITCHBLADE, FOR BROADLEAF WEED CONTROL. Matthew C. Fleetwood*1, Jeff Marvin2, Dale Sanson2, Xi Xiong1;

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Broadleaf weed control on managed turf typically relies on applications of synthetic auxins, such as 2,4-dichlorophenoxyacetic acid (2,4-D), dicamba, and methylchlorophenoxypropionic acid (MCPP). Some of the common broadleaf weeds growing on residential lawns, including dandelion (Taraxacum officinale F. H. Wigg.), prostrate knotweed (Polygonum aviculare L.) and white clover (Trifolium repens L.), can be effectively controlled by applications of traditional three-way combinations of synthetic auxins, compared to other species such as Korean lespedeza (Kummerowia stipulacea (Maxim.)). Recently, a novel synthetic auxin herbicide, halauxifen-methyl, representing a new chemical class, is entering the turf market under the trade name of Switchblade™. This line of herbicide contains halauxifen-methyl, along with two other synthetic auxins dicamba and fluroxypyr. The objective of this experiment was therefore to evaluate the efficacy of Switchblade™ for control of common broadleaf weeds on cool-season turf. Field experiments were conducted at the University of Missouri South Farm in Columbia, Missouri, where target weeds naturally occurred or were over-seeded prior to treatment application. POST application of Switchblade™ at two rates, and a commercial product containing a mixture of 2,4-D, MCPP and dicamba were applied to individual plots measuring 1.5 m × 1.5 m, in addition to a nontreated control. Treatments were arranged in a randomized complete block deign with four replications. A CO2 pressurized backpack sprayer equipped with XR8004 flat fan tips and calibrated at 374 L ha-1 was used for applications. Evaluations included weekly assessment of percent weed coverage (0-100), percent weed control (0-100), and area under percent weed curve (AUPWC) over the season. Regardless of rate, herbicide-containing halauxifen had comparable efficacy to the commercial product for control of prostrate knotweed, white clover and buckhorn plantain (Plantago coronopus L.). The herbicide containing halauxifen suppressed lespedeza and resulted in up to 92% control at 10 wk after treatment (WAT). In comparison, the commercial product suppressed 46% of lespedeza at 10 WAT. Our results suggested that herbicide containing halauxifen could be a very useful tool in the turf market for some of the hard-to-kill broadleaf weeds.

RESIDUAL HERBICIDE ACTIVITY AS INFLUENCED BY APPLICATION TO SOIL COVERED WITH CROP RESIDUE. Ethan Johnson*1, Brent Heaton2, Mark Bernards1; 1Western Illinois University, Macomb, IL, 2Western Illinois University, Industry, IL (68)

Cover crops are being used more frequently because of their positive effects on nitrogen sequestration and soil health. Applying residual herbicides to living plant material or heavy crop residue may result in the herbicide becoming sequestered in the plant material and never reaching the soil solution where it acts to control newly germinated weeds. Little is published regarding weed control as it is affected by applying herbicides to different types of plant residue. We hypothesized that increasing crop residue would reduce the effectiveness of residual herbicides. A randomized complete block design experiment with four replications was established on a Keomah silt loam soil at the WIU Agricultural Field Laboratory in Macomb, IL. The field was planted to soybean in 2016 and a cereal rye (Secale cereal) cover crop was established following soybean harvest. Burndown herbicide treatments of 1740 g ae ha-1 glyphosate were applied to terminate rye in nine treatments on April 18. Herbicide treatments were applied using a CO2 pressurized backpack sprayer and a four nozzle boom calibrated to deliver 140 L ha-1. Corn (Zea mays) hybrid DKC60-67 was planted in 76 cm rows at 88,000 seeds ha-1 on May 17. Waterhemp and other summer annual weeds had emerged by the time of planting. Weed counts were made in three 0.09 m2 quadrats per plot at the time of planting to use as a covariate for subsequent weed count analysis. Burndown applications of glufosinate-ammonium (590 g ha-1) plus ammonium sulfate (2% w v-1) were made to plots to control emerged summer annual weeds and the remaining cereal rye cover crop. There were four residue treatments: 1) rye terminated four wk before planting, 2) rye terminated at the time of planting, 3) all surface residue removed by raking at planting, and 4) corn stover residue added to provide >90% residue cover at planting. Imposed on the residue treatments were residual herbicide treatments: 1) untreated, 2) a pre-mixture of s-metolachlor (508 g ha-1) + atrazine (237 g ha-1) + mesotrione (56 g ha-1) + bicyclopyrone (14 g ha-1), and 3) acetochlor (2530 g ha-1) + atrazine (1000 g ha-1). Applications were at the time of planting. Crop residue biomass was collected one wk after planting from three 0.09 m2 quadrats per plot, dried, and then weighed. Similarly, weed counts and weed biomass were collected from three 0.09 m2 quadrats in each plot at four and six wk after planting (WAP). The experiment received 544 mL of precipitation within 48 hr of applying the residual herbicides, and an additional 376 mL within seven d. Corn plant populations were reduced 70% in plots where the rye was not terminated until the time of corn planting, and 30% where corn stover was added. Waterhemp counts at four WAP were greater in treatments where herbicides were not applied when compared to treatments where herbicides were applied for all residue levels, except corn stover, where waterhemp counts were low and equal for all three herbicide treatments. Similarly, at six WAP waterhemp counts were greatest where no herbicide was applied for all residue levels. There were no differences in waterhemp counts between the two herbicides used in the study.

INFLUENCE OF FALL ESTABLISHMENT AND SPRING TERMINATION TIMINGS OF ANNUAL RYEGRASS ON CORN YIELDS. Taylor Campbell*1, Joe Ikley2, Bill Johnson3; 1Purdue University, Lafayette, IN, 2Purdue University, West Lafayette, IN, 3Purdue University, W Lafayette, IN (69)

With the adoption of cover crops, farmers need to be aware of best management options to ensure crop yields are not reduced. Annual ryegrass (Lolium multiflorum) has been reported to reduce corn yields when planted as cover crop before corn. The objective of this study was to determine if establishment and termination timings of annual ryegrass influenced crop yields in the following corn crop. Annual ryegrass growth and survival was influenced by the different establishment timings. In 2015 corn yields were influenced by establishment timings. Plots where annual ryegrass was established earlier produced 2826 kg ha-1 more than plots where annual ryegrass was establishment at the latest timing. Termination timing did not influence yields in 2015. In 2016, there was an interaction between establishment and termination timing. The highest yielding plots were those terminated the earliest and had yields ranging from 11512 to 10863 kg ha-1. The lowest yielding plots were those established the earliest and terminated the latest, with an average yield of 5170 kg ha-1. These results demonstrate that annual ryegrass can influence corn yields but results vary from year to year. We recommend farmers be cautious of using annual ryegrass as a cover crop before corn, and if annual ryegrass is used, they should terminate annual ryegrass before planting corn to reduce competition between emerging corn plants and mature annual ryegrass plants.

IMPACT OF COVER CROP SPECIES SELECTION ON SOIL MOISTURE AND CORN DEVELOPMENT IN SEMI-ARID RAINFED CROPPING SYSTEMS OF WESTERN NEBRASKA. Alexandre T. Rosa*1, Liberty Butts2, Cody Creech3, Roger Elmore1, Daran Rudnick4, Rodrigo Werle1; 1University of Nebraska-Lincoln, Lincoln, NE, 2University of Nebraska Lincoln, North Platte, NE, 3University of Nebraska-Lincoln, Scottsbluff, NE, 4University of Nebraska-Lincoln, North Platte, NE (70)

Cover crops (CC) have increased in popularity across the US. Producers in semi-arid regions such as western Nebraska are questioning whether and which CC species would fit in their cropping systems without impacting crop yields. Benefits of CC are potential increase in soil fertility, reduced soil erosion, and weed suppression. In a water-limited environment, CC may use excessive soil water, which may reduce yield of the subsequent crop. The objective of this study was to examine biomass production of different CC species and how they impact subsequent soil moisture levels and corn productivity. The trial was conducted in a randomized complete block design with four replications at two locations in western Nebraska (North Platte and Grant, NE). Treatments consisted of: 1) no CC, 2) spring triticale, 3) cereal rye, 4) spring oat, 5) purple top turnip, 6) Siberian kale, 7) balansa clover, and 8) hairy vetch. Cover crops were drilled early-September 2016 following winter wheat harvest. CC biomass was collected during fall of 2016 and spring of 2017. CC were terminated at corn planting time. Corn was planted early to mid-May 2017. Soil moisture readings were taken from 0-20 cm deep at corn planting, V4 and V6 growth stages. Corn biomass was collected at V6 growth stage. Initial findings illustrate noticeable differences in CC biomass in the fall. At Grant, cereal rye produced the highest amount of biomass. At North Platte, Siberian kale produced the highest amount of biomass. At both locations, balansa clover presented the lowest biomass accumulation. In the spring, only three CC species produced measurable CC biomass at both sites: spring triticale, cereal rye and hairy vetch. Soil moisture readings at corn planting illustrated differences amongst CC treatments. Cereal rye reduced water availability at corn planting in North Platte. At Grant, cereal rye, spring triticale and hairy vetch reduced corn biomass. Results of this study will help guide CC species selection for rainfed cropping systems of semi-arid environments.

EFFECTS OF TIMING OF WEED REMOVAL AND PRE HERBICIDES ON GROWTH AND YIELD OF CORN. Ayse Nur Ulusoy*1, O. Adewale Osipitan2, Jon E Scott3, Stevan Z. Knezevic2; 1University of Nebraska-Lincoln, Lincoln, NE, 2University of Nebraska-Lincoln, Concord, NE, 3University of Nebraska, Concord, NE (71)

A field study was conducted at the experimental farm of Haskell Agricultural Laboratory, Concord, Nebraska in 2017 to evaluate how timing of weed removal and PRE herbicides for control of early emerging weeds could influence growth and yield of glyphosate-tolerant corn. The study was arranged in a split-plot design with 21 treatments; three herbicide regimes (No PRE and PRE application of two herbicides) as main plots and seven weed removal times (V3, V6, V9, V12, V15 corn growth stages as well as weed free and weedy season long) as sub-plots in four replications. The two PRE herbicides were atrazine and atrazine plus bicyclopyrone plus mesotrione plus s-metolachlor. Corn growth parameters were collected at corn tasseling stage (VT growth stage) and these included: plant height, leaf area per plant, leaf area index and shoot dry weight. Corn yield and yield components were collected at physiological maturity and included: number of ear per plant, number of kernels per ear, 100 kernel weight and grain yield. Delay in weed removal timing reduced leaf area index, shoot dry weight, number of kernels per ear, and yield. Generally, PRE application of herbicide delayed reduction in shoot dry weight and grain yield compared to No PRE; the delays were greater in the subplots sprayed with atrazine plus bicyclopyrone plus mesotrione plus s-metolachlor than atrazine, suggesting that atrazine plus bicyclopyrone plus mesotrione plus s-metolachlor protected the crop for a longer period than atrazine alone. For example, 5% reduction in corn dry weight occurred when weed removal was delayed until 92 GDD after emergence (V2 growth stage) without PRE herbicide, while the PRE application of atrazine plus bicyclopyrone plus mesotrione plus s-metolachlor or atrazine allowed corn to grow until 301 GDD (V7 growth stage) and 162 GDD (V5 growth stage) respectively, to reach the same 5% threshold. Weed free corn produced an average of 620 kernels ear-1 but this declined as weed removal was delayed, particularly when no PRE herbicide was applied. The threshold level of 5% yield reduction occurred when weed removal was delayed until 222 GDD (V4 growth stage) without PRE herbicide, while PRE application of atrazine plus bicyclopyrone plus mesotrione plus s-metolachlor and atrazine protected corn yields and delayed the 5% threshold till 483 GDD (V11 growth stage) and 301 GDD (V7 growth stage), respectively. These results demonstrated that PRE application of herbicide does provide a longer weed free environment for corn growth and yield.

POSTEMERGENCE HERBICIDES FOR WEED CONTROL IN ORGANIC CORN AND SOYBEANS. Betzabet Valdez*1, Reid Smeda2; 1University of Missouri, Columbia, Columbia, MO, 2University of Missouri, Columbia, MO (72)

Organic production systems for agronomic crops are highly dependent on cultural practices (cover crop) and mechanical cultivation for weed control. Optimum yields are mostly associated with the effectiveness of weed suppression. The objective of this research was to determine if effective weed control in corn and soybean could be achieved with organic, contact herbicides applied as a directed spray between crop rows. Soybeans and corn were planted in 76-cm rows at the Bradford Research and Extension Center. As weeds reached 8 cm in height, repeated application of plant oils (manuka, clove + cinanamon, limonene) and acids (acetic, caprylic + capric) were made at 374 L ha-1 using a shielded sprayer. A total of five to six organic herbicide applications were made between crop emergence until crops reached canopy closure. At the end of the season, herbicides reduced weed biomass by 51 to 84% in corn and 84 to 100% in soybean. Caprylic + capric acid was the effective treatment in both cropping systems. Despite effective weed control, caprylic negatively impacted soybean yield (0.1% yield loss compared untreated control) but resulted in a 59% increase in corn yield. Relative to the untreated control, four of the five herbicide applications negatively impacted soybean yield while only one treatment negatively impacted corn yield. Organic herbicides show promise for weed control in corn and soybean production systems, but the non-selective aspect of herbicides will require caution during the application process.

WEED CONTROL FOLLOWING SINGLE-PASS PRE OR POST CORN HERBICIDES AS AFFECTED BY PLANTING DATE. Luke Merritt*1, Brent Heaton2, Mark Bernards1; 1Western Illinois University, Macomb, IL, 2Western Illinois University, Industry, IL (73)

Each weed species has a unique emergence pattern which influences appropriate control measures. For example, Chenopodium album emergence lasts from April to late June (Werle 2014). This presents a challenge for effective weed management. In a study evaluating the effect of soybean planting date on weed control, late planted soybeans competed with fewer weeds but yielded less than early planted soybeans (Davis 2013). Similarly, weed intensity was less for sweet corn (Zea maize) planted in mid-June compared to sweet corn planted in early May (Williams 2006). In an organic corn production system, weed biomass was lower in later planted corn when compared to early planted (Teasdale 2015). Glyphosate-resistant weeds are becoming more of an issue for corn producers. Should we plant late in the spring and till immediately prior to planting to mechanically destroy the majority of the weed population for the growing season? Should planting date be a management strategy to control weeds, even though yield potential is generally lower for later planted corn? The objective of this study was to evaluate weed control on different one-pass PRE and one-pass POST herbicide programs and corn yield in response to early, normal and late planting dates. Our hypothesis was that delayed planting date will reduce weed interference and density but decrease in yield. Corn (Dekalb 60-67 RIB) was planted in 76-cm rows at 88,000 seeds ha-1 on 4/10, 5/1, and 5/22/2017 at the Western Illinois University Agricultural Field Laboratory in Macomb, IL. There were two adjacent experiments, each arranged in a randomized complete block design with four replications. Plots were 3 x 10.7 m. The first factor in each experiment was planting date (see above). Each plot was field cultivated immediately before planting. The second factor was herbicide treatment. One experiment included only preemergence (PRE) herbicides, and the second included only postemergence (POST) herbicides. The PRE herbicide treatments used were 1) a pre-mixture of s-metolachlor (1350 g ha-1) + atrazine (631 g ha-1) + mesotrione (151 g ha-1) + bicyclopyrone (38 g ha-1), 2) a pre-mixture of thiencarbazone-methyl (37 g ha-1) + isoxaflutole (92 g ha-1) plus tank-mixture with atrazine (1120 g ha-1) , 3) a pre-mixture of acetochlor (2435 g ha-1) + atrazine (1964 g ha-1), and 4) a pre-mixture of saflufenacil (90 g ha-1) + dimethenamid-P (790 g ha-1). PRE herbicides were applied shortly after each planting date: 13 April, 6 May, and 29 May, respectively. The post herbicide treatments were 1) a pre-mixture of topramezone (18 g ha-1) + dimethenamid (922 g ha-1) tank-mixture with glyphosate (1100 g ae ha-1) and atrazine (560 g ha-1), 2) a pre-mixture of s-metolachlor (1048 g ha-1) + glyphosate (1048 ae g ha-1) + mesotrione (105 g ha-1) tank-mixture with atrazine (560 g ha-1), 3) a pre-mixture of Na-diflufenzopyr (55 g ha-1) + Na-dicamba (141 g ha-1) tank-mixture with glyphosate (1100 g ha-1) and atrazine (560 g ha-1), and 4) a pre-mixture of thiencarbazone-methy (15 g ha-1) + tembotrione (76 g ha-1) tank-mixture with glyphosate (1100 g ha-1) and atrazine (560 g ha-1). POST herbicides were applied within three wk of emergence for each planting date: 3 May, 25 May, and 19 June, respectively. PRE and POST herbicides were applied using a back-pack sprayer calibrated to deliver 140 L ha-1 with a four nozzle boom. Weeds present in the study area included Amaranthus tuberculatus, Chenopodium album, Xanthium strumarium, Ipomoea spp., Lamium amplexicaule, and various grass species. Weed control was estimated visually at 21, 42, and 56 d after planting and preharvest. Weed seed counts were collected in the untreated checks before harvest. Yield was measured using a plot combine and moisture was adjusted to 15.5% for yield calculations. Contrary to expectations, yield increased as planting was delayed. One possible explanation was extremely dry conditions prior to tasseling for the Aprl 10 planting. In the untreated checks, Amarantus tuberculatus and Ipomea spp. weed seed production decreased as planting date was delayed from early-April to late-May.

MANAGEMENT OF PALMER AMARANTH USING A PREMIX OF DICAMBA AND TEMBOTRIONE IN CORN. Amy D. Hauver*1, Parminder Chahal2, Kevin Watteyne3, Amit J. Jhala2; 1University Nebraska Lincoln, Lincoln, NE, 2University of Nebraska-Lincoln, Lincoln, NE, 3Bayer CropScience, Lincoln, NE (74)

Palmer amaranth (Amaranthus palmeri) is a pervasive and economically damaging weed in several crops in the US. The objective of this study was to evaluate different site of action herbicide pre-mixture applied POST for Palmer amaranth control in glyphosate- plus glufosinate-resistant corn. A field study was conducted at South Central Agricultural Laboratory (SCAL), Nebraska in 2017 and 11 herbicide treatments were laid out in a randomized complete block design with four replications. POST herbicides were applied when Palmer amaranth was 10-12 cm tall. Atrazine plus bicyclopyrone plus mesotrione plus s-metolachlor, or acetochlor plus clopyralid plus mesotrione pre-mixtures provided 73 to 93% control, comparable with dicamba plus tembotrione tank-mixtures with atrazine, atrazine plus glyphosate, or atrazine plus glufosinate at 28 d after treatment (DAT). Similarly, the above-mentioned POST herbicide treatments provided 65 to 95% control at 42 DAT. The control was quite variable in the study due to uneven distribution of Palmer amaranth at the experimental site. PRE herbicides were not applied in this study and a high population of Palmer amaranth was present at the time of POST herbicide applications which resulted in lower and more variable control. In addition, Palmer amaranth has an extended period of emergence (March to October) in the Midwest US, making it difficult to control. To achieve season-long Palmer amaranth control and to reduce the evolution of HR weeds, different site of action soil-residual herbicides can be applied within two to three days of crop planting and in tank mixture with foliar active herbicides in a POST application.

POST CORN HERBICIDE OPTIONS FOR CONTROL OF GLYPHOSATE-RESISTANT PALMER AMARANTH IN WESTERN NEBRASKA. Clint W. Beiermann*1, Nevin C. Lawrence1, Stevan Z. Knezevic2, Amit Jhala3, Cody Creech1; 1University of Nebraska-Lincoln, Scottsbluff, NE, 2University of Nebraska-Lincoln, Concord, NE, 3University of Nebraska-Lincoln, Lincoln, NE (75)

Palmer amaranth resistance to ALS- and EPSPS-inhibiting herbicides is increasing in western Nebraska. Herbicide options are limited in dry bean and sugarbeet, common crops in the region. Attaining near complete control of Palmer amaranth in corn is essential for reducing the soil seed bank prior to planting rotational crops. This goal is complicated by limited PRE and POST herbicide options due to crop rotation restrictions. Group 4, TIR1 auxin receptors, and group 15, long-chain fatty acid inhibiting herbicides, applied POST in corn allow rotation to sugarbeet or dry bean the following year. The study objective was to find the best combination of group 4 and 15 herbicides for controlling late emerging Palmer amaranth in corn. 2,4-D, dicamba, and dicamba + diflufenzopyr were applied alone and in combination with four long-chain fatty acid inhibitors (dimethenamid-P, s-metolachlor, acetochlor, and pyroxasulfone). Herbicides were applied when corn was at V4 and Palmer amaranth was five cm in height. Visual estimations of control six wk after application were higher for treatments containing dicamba or dicamba + diflufenzopyr than treatments containing 2,4-D. Treatments containing dicamba or dicamba + diflufenzopyr resulted in lower Palmer amaranth density compared to treatments containing 2,4-D. Treatments containing dicamba + diflufenzopyr had lower Palmer amaranth biomass than treatments containing 2,4-D. Treatments containing dicamba + diflufenzopyr yielded more than treatments containing 2,4-D. There was limited benefit from adding a group 15 herbicide to group 4 containing POST treatments, with no additional benefit in respect to most response variables.

CORN BARRIER EFFECT ON HERBICIDE DRIFT. Bruno Canella Vieira*1, Thomas R. Butts2, Andre O. Rodrigues2, Kasey Schroeder2, Jeffrey Golus2, Greg R Kruger3; 1University of Nebraska, Lincoln, NE, 2University of Nebraska-Lincoln, North Platte, NE, 3University of Nebraska, North Platte, NE (76)

Pesticide drift is one of the main factors reducing the efficiency of herbicide applications. More importantly, herbicide drift has the potential to cause severe impacts on susceptible vegetation depending on the herbicide mode of action, exposure level, and the vegetation tolerance to the herbicide. Spray drift is directly influenced by weather conditions, surrounding environment, physicochemical properties of the spray solution, and the application technique. The advent of vegetative windbreaks in spray drift mitigation has been discussed in the literature, where barrier characteristics such as density, width, height, leaf area index, and number of rows influence the windbreak efficiency. This study aimed to investigate the potential use of corn rows on the edge of fields as an effective "barrier" to mitigate drift in herbicide applications. The study also aimed to understand the influence of corn height in drift reduction, and the effectiveness of the corn barrier in mitigating drift from two different droplet size spectra (Medium and Ultra Coarse). A field experiment was conducted in the West Central Water Resources Field Laboratory, University of Nebraska – Lincoln in Brule, NE. Eight corn rows were planted at three different timings (70 m sections) and maintained on the edge of the experimental field prior to the study application. At the time of application, corn plants were 91-, 122-, and 198-cm tall for each planting timing, respectively. Applications (94 L ha-1) were made with a 30.5 m boom self-propelled sprayer with a 0.6 ppm tank solution of water and the fluorescent tracer PTSA (1,3,6,8-pyrene tetra sulfonic acid tetra sodium salt). The tank solution was sprayed at 276 kPa with two different nozzles: ER11004 (Medium droplets) and TTI11004 (Ultra Coarse droplets). Applications were made from east to west in a south crosswind 12 times for each nozzle in a completely randomized design. Mylar cards (100 cm2) were used as drift collectors at different downwind distances (0, 2, 5, 10, 14, 22, 29, 105, 32, 53, and 70 m) from the treated area of each corn section (no corn, 91-, 122-, and 198-cm tall). Drift (%) was estimated for each downwind collector by fluorimetry analysis. A double exponential decay model was fitted to the data using the gnm package in R. Applications with Ultra Coarse droplets resulted in greater in-swath deposition (93%) when compared to the Medium droplets (84%), indicating that the later had greater off-target movement. Corn barriers were efficient in mitigating application drift in both droplet spectra scenarios, especially in shorter downwind distances. The advent of corn rows as a barrier could be considered as an effective practice to mitigate off-target movement in herbicide applications.

OPTIMIZING A COVER CROP PROGRAM FOR THE CONTROL OF GLYPHOSATE-RESISTANT

HORSEWEED. Alyssa Lamb*1, Mark Loux2; 1The Ohio State University, Columbus, OH, 2Ohio State University, Columbus, OH (77)

Glyphosate resistance was first reported in horseweed (Conyza canadensis) in 2000 and has since spread throughout midwestern crop production fields. Overuse of glyphosate and a limited number of control options have made it one of the most problematic weeds in soybean (Glycine max) fields, especially under no-till conditions. Cover crops have been a part of conservation practices for many years and are being adopted by a growing number of farmers. Most commonly used as a soil conservation method, cover crops may also have the ability to suppress weed populations. Cereal rye (Secale cereale) has proved to be a hardy cover crop that is more difficult to winter kill and has a more flexible planting window than many other cover crop species. Two field trials were conducted from fall of 2016 through fall of 2017 at the OARDC Western Agricultural Research Station in South Charleston, Ohio with the goal of optimizing the use of a cereal rye cover crop for the control of glyphosate-resistant horseweed. The objectives of this research were to: (1) determine the effect of planting date and seeding rate of a cereal rye cover crop on horseweed population density and control; (2) determine the effects of different levels of spring residual herbicides on horseweed population density and control; (3) determine whether optimizing the fall cover crop growth can consistently replace the fall herbicide application for glyphosate-resistant horseweed. Treatments were arranged in a randomized complete block with a split-split-plot randomization and four replications. The factors in the first study were: cover planting date (September 27 and October 26), cover seeding density (0, 50, and 100 kg ha-1), and levels of spring residual herbicide (none, metribuzin only, and metribuzin + flumioxazin). The factors in the second study were the same for planting date and seeding density, and the third factor was level of fall herbicide (none and 2,4-D). Data were analyzed as a factorial design using the PROC GLIMMEX procedure in SAS with at $\alpha = 0.05$. In the first study, the late-April horseweed population was not sufficient to allow for analysis. In the second study, averaged over other factors, the horseweed population density in late-April was higher where there was no cover, 73 plants m-2 compared with the low and high seeding densities, 12 and 3 plants m-2, respectively. Inclusion of a fall herbicide treatment reduced the horseweed density from 52 to 7 plants m-2, averaged over other factors. In mid-June, horseweed density was affected by cover seeding rate and herbicide factors in both studies, but not by cover planting date. In the first study, horseweed density was higher in the absence of a cover compared with the highest seeding density, and lowest at the high residual herbicide level, averaged over other factors. In the second study, mid-June results were consistent with those in late-April. The horseweed populations remained close to those levels until harvest, with seeding rate and herbicide level affecting density. There was no effect of treatments on soybean yield. In the first and second study, horseweed density in June was reduced by 1.4 and 4.3 plants m-2, respectively, for every additional thousand kg ha-1 of spring biomass, averaged over all factors. These results suggest that increasing the density of a rye cover crop can improve its ability to suppress horseweed and increase its overall contribution to control, but may not allow for reductions in herbicide use.

WEED MANAGEMENT IN SOYBEAN INTERCROPPED WITH SPRING PLANTED RYE. Zachary Brewer*1, Brent Heaton2, Mark Bernards1; 1Western Illinois University, Macomb, IL, 2Western Illinois University, Industry, IL (78)

As the prevalence of herbicide resistance continues to increase in waterhemp (Amaranthus tuberculatus) populations there is a need to identify non-herbicide tactics to help manage these populations. One potential tactic is intercropping. Intercropping is a system in which two or more crops are grown in the same field at the same time. Cereal rye (Secale cereal), planted in the spring with soybean (Glycine max), will remain in a vegetative state and will be shorter than the soybean but may suppress summer annual weed growth. The commercialization of dicamba-resistant soybeans creates an opportunity to apply herbicides that will target waterhemp without killing a cereal rye cover crop. In this experiment, we predicted that using herbicides in conjunction with intercropped cereal rye would improve waterhemp control compared to herbicides alone. The experiment was established on the WIU Kerr Agronomy Farm. It was arranged in a randomized complete block design with three replications. Plots were three m wide by 6.1 m long. The field contained a Rozetta silt-loam and had been in no-till corn for the previous three years. There were six treatments in the study: 1) dicamba (560 g ae ha-1) + glyphosate (1260 g ae ha-1) applied three wk after soybean planting (WAP); 2) saflufenacil (25 g ha-1) + pyroxasulfone (120 g ha-1) applied zero WAP followed by dicamba (560 g ha-1) + glyphosate (1260 g ha-1) applied three WAP; 3) intercropped rye planted zero WAP followed by dicamba (560 g ha-1) applied three WAP; 4) saflufenacil (25 g ha-1) + intercropped rye at zero WAP followed by dicamba (560 g ha-1) + pyroxasulfone (120 g ha-1) applied three WAP; 5) glyphosate (1260 g ha-1) applied three WAP and rye intercropped four WAP; 6) safulfenacil applied zero WAP followed by glyphosate (1260 g ha-1) applied three WAP followed by rye intercropped four WAP. AG36X6 soybeans were planted in 76-cm rows at 395,000 seeds ha-1 on 5/30/2017. Cereal rye (45 kg ha-1) and creeping red fescue (67 kg ha-1) were drilled using a 3 m wide no-till drill into two treatments on May 30. On June 29, rye and creeping red fescue (Festuca rubra) were drilled into two additional treatments. Preemergence herbicides were applied on May 31 using a CO2 backpack sprayer and a six nozzle boom equipped with TT11002 nozzles calibrated to deliver 140 L ha-1. Postemergence herbicides were applied June 23 using TTI11002 nozzles. The most prevalent weed in the field was waterhemp. Visual estimations of weed control were recorded at 2, 6 and 14 wk after the POST application on a scale where 0 = no control and 100 = plant death. Both cover crop and weed biomass was collected on June 23 and July 20 from four (0.09 m2) in each plot. Waterhemp plants were counted prior to cutting each sample and weeds and cover crops were placed in separate bags, dried and weighed. Only weed biomass was collected October 13 because the rye had senesced. Canopy closure was rated on August 3 and August 29 by measuring the distance between the outermost leaves on the plants in the center two rows of each plot. Growth data, including soybean growth stages, soybean plant heights (cm), and node counts on the soybeans was assessed bi-weekly throughout the growing season in each plot at 15, 30, and 45 m from the front of the plots. Soybeans were harvested using a plot combine, and weights were adjusted to 13% moisture in calculating yields. Data were subjected to ANOVA, and means were separated using LSD. The creeping red fescue did not establish successfully because of dry conditions after planting. Interplanting cereal ryegrass with soybean had no effect on soybean yield, but did reduce soybean height and delayed canopy closure when cereal rye was drilled at the time of soybean planting. Rye biomass was greater when rye was planted at the same time as soybeans. Little rye biomass accumulated from the June 29 interplanting because of poor stand establishment. Weed control estimates were greater for the herbicide-only treatments than for the rye interplant treatments. However, there was no difference in weed biomass collected between the May 30 rye interplanted treatments and the herbicide only treatments. In conclusion, we reject the hypothesis because intercropped rye combined with herbicides did not improve waterhemp control compared to the herbicide-only treatments.

INTEGRATION OF RESIDUAL HERBICIDES AND COVER CROPS FOR WEED CONTROL IN A SOYBEAN PRODUCTION SYSTEM. Derek Whalen*, Mandy Bish, Kevin W Bradley; University of Missouri, Columbia, MO (79)

Cover crops have increased in popularity in Midwest corn and soybean production systems in recent years. One of the potential benefits that cover crops can provide is to reduce weed emergence or growth through the release of allelopathic chemicals into the weed-rooting zone and/or through the creation of a physical mulch barrier. However, little research has been conducted to evaluate how cover crops and pre-emergence, residual herbicides are most appropriately integrated together in a soybean production system. Field studies were conducted in 2016 and 2017 to evaluate summer annual weed control in response to six different cover crops combined with herbicide applications, which consisted of pre-plant applications of glyphosate plus 2,4-D with or without sulfentrazone plus chlorimuron. Pre-plant applications were made at two different timings, 21 and 7 d prior to planting (DPP). The cover crops evaluated included hairy vetch, cereal rye, Italian ryegrass, oats, Austrian winter pea, wheat and a mixture of hairy vetch and cereal rye. These same herbicide treatments were applied to tilled and no-tilled soil without any cover crop for comparison. Visual estimations of weed control, groundcover and cover crop control were collected at regular intervals after planting. Weed density counts were conducted when soybean reached R5. Soil and cover crop samples were taken at 0, 14, 28, 56 and 84 d after the two pre-plant timings to quantify sulfentrazone residue levels. Data were subjected to analysis using the PROC GLIMMIX procedure in SAS, and means were separated using Fisher's Protected LSD ($P \leq 0.05$). Greater than 73% control of waterhemp was achieved across cover crops that included a residual herbicide treatment, which was higher than the control achieved by any of the treatments that included glyphosate plus 2,4-D alone. Cover crops that had a residual herbicide applied had higher weed control (77%) than cover crops without (38%). When applied PRE, herbicide treatments with sulfentrazone had higher weed control 21 DPP than 7 DPP. When evaluating the interaction of cover crop species and herbicide treatments, those that included a residual herbicide applied 21 DPP provided higher weed control than treatments without a residual when applied to tilled soil without any cover crop, no-till soil without a cover crop, hairy vetch, Austrian winter pea and the mixture of hairy vetch and cereal rye. Results from these studies will provide useful information on integrating cover crops and residual herbicides in soybean production in order to provide more options for the control of herbicide-resistant weed species like waterhemp.

COMBINING HERBICIDE PROGRAMS AND CEREAL RYE COVER CROP FOR INTEGRATED WEED MANAGEMENT IN SOYBEANS. Adam Striegel*1, Liberty Butts2, Nikola Arsenijevic3, Gustavo Vieira3, Alexandre T. Rosa1, Christopher Proctor1, Rodrigo Werle1; 1University of Nebraska-Lincoln, Lincoln, NE, 2University of Nebraska Lincoln, North Platte, NE, 3University of Nebraska-Lincoln, North Platte, NE (80)

The utilization of cereal rye as a cover crop in Midwestern corn-soybean rotation has increased in popularity with many producers. Most commonly cited are the suite of soil conservation benefits, however, cereal rye has been documented for its potential to suppress weeds. The objective of this study was to evaluate cereal rye cover crop in combination with different herbicide programs to enhance weed control in soybeans. Two sites located in west-central Nebraska (North Platte and Grant) were established in the fall of 2016 in fields rotating from corn to soybeans in 2017. Experimental treatments consisted of: i) no cover crop, cereal rye cover crop terminated in early spring (mid-April), or terminated at planting and ii) herbicide programs including or excluding fall burndown, early spring burndown, and/or at-planting residual. The experiment was conducted as a randomized complete block design with four replications. Cereal rye biomass at termination, end of cropping season cereal rye biomass residue, weed density and biomass samples were collected. The impact of cereal rye on weed suppression varied across locations. At North Platte, cereal rye alone terminated at planting reduced weed biomass and density by >85% compared to the no-cover crop control whereas at Grant >30% weed reduction was observed. North Platter received higher precipitation and kochia and common lambsquarters were the predominant weed species; Palmer amaranth was the predominant species at Grant. The different spectrum of weed species and precipitation between sites most likely explains why cereal rye was more effective at suppressing weeds at North Platte. Cereal rye treatments alone did not provide complete weed control, but in combination with at-planting residual herbicides, weed control was similar to no cover crop treatments where burndown herbicides were sprayed in the fall or spring followed by at-planting residual herbicides. Our results indicate that fall-planted cereal rye cover crop could potentially replace a fall or early spring burndown application and thus be utilized as an effective component of an integrated weed management system.

EFFECTS OF TIMING OF WEED REMOVAL AND PRE HERBICIDES ON GROWTH AND YIELD OF SOYBEAN. Pavle Pavlovic*1, Amit Jhala2, Ethann R. Barnes2, Clint Beiermann3, Nevin C. Lawrence4, Jon E Scott5, O. Adewale Osipitan1, Stevan Z. Knezevic1; 1University of Nebraska-Lincoln, Concord, NE, 2University of Nebraska-Lincoln, Lincoln, NE, 3University of Nebraska, Scottsbluff, NE, 4University of Nebraska-Lincoln, Scottsbluff, NE, 5University of Nebraska, Concord, NE (81)

Growth and yield of soybeans can be affected by numerous factors. The most influential one is competition from weeds. Field studies were conducted in 2017 at Concord and Clay Center, NE to evaluate how timing of weed removal and application of PRE-herbicides influence growth and yield of soybean. The studies were arranged in a split-plot arrangement of 14 treatments (two herbicide regimes and seven weed removal times) with four replicates. The two herbicide regimes were: No PRE and PRE application of sulfentrazone plus imazethapyr at 420 g ai ha-1 at Concord or saflufenacil plus imazethapyr plus pyroxasulfone at 215 g ai ha-1 at Clay Center. The seven weed removal times were: V1, V3, V6, R2 and R5 soybean growth stages, as well as weed free and weedy season long. Soybean growth parameters were collected at Concord and these included: height, leaf area, leaf area index and shoot dry weight at R6 growth stage. Soybean yield and yield components were collected at both locations, and these included: grain yield, number of pods plant-1, number of seeds pod-1 and 100 seed weight. Delayed timing of weed removal reduced shoot dry weight and grain yield of soybean. A 5% reduction in soybean dry weight occurred when weed removal was delayed until 100 GDD after emergence (V1 soybean stage) without PRE herbicide application, while the use of PRE herbicide allowed soybean to grow until 382 GDD after emergence (V5 soybean stage) to reach the same 5% threshold. Weed free soybean yielded 4416 kg ha-1. The threshold level of 5% yield loss occurred when weed removal was delayed until 161 GDD after emergence (V1 soybean stage) without PRE herbicide. Application of PRE herbicide protected soybean yields and the 5% threshold occurred at 530 GDD after emergence (V6 soybean stage) at Concord site. Similar results occurred at Clay Center, demonstrating that PRE herbicides protected soybean growth and yields.

INFLUENCE OF LATE EMERGING WEEDS ON THE YIELD OF GLYPHOSATE-RESISTANT SOYBEAN. Nader Soltani*1, Amit Jhala2, Robert E. Nurse3, Peter H Sikkema1; 1University of Guelph, Ridgetown, ON, 2University of Nebraska-Lincoln, Lincoln, NE, 3Agriculture Canada, Harrow, ON (82)

A study consisting of thirteen field experiments was conducted during 2014 to 2016 in southwestern Ontario and southcentral Nebraska to determine the effect of late emerging weeds on yield of glyphosate-resistant soybean. Soybean was maintained weed-free with glyphosate (900 g ae ha-1) up to VC (cotyledon), V1 (first trifoliate), V2 (second trifoliate), V3 (third trifoliate), V4 (fourth trifoliate), and R1 (beginning of flowering) growth stage after which weeds were allowed to naturally infest soybean. At six wk after the last glyphosate application (WAA), total weed biomass was reduced 63, 90, 98, 100, 100, and 100% at Exeter; 12, 77, 94, 95, 97, and 100% at Harrow; 28, 100, 100, 100, 100, and 100% at Clay Center, Nebraska; and 58, 87, 94, 98, 97, and 99% at Ridgetown when soybean was maintained weed free up to VC, V1, V2, V3, V4, and R1 growth stage, respectively. The critical weed-free period for 1, 2.5, 5, and 10% yield loss in soybean was VC to V1, VC to V1, VC to V1 and VE to VC growth stages at Exeter; V2-V3, V1-V2, V1-V2 and VC-V1 growth stage at Harrow; V4-R1, V2-V3, V2-V3 and V1-V2 growth stage at Nebraska; and V3-V4, V1-V2,VC-V1 and VC-V1 growth stage at Ridgetown, respectively. For weeds evaluated, there was a minimal reduction in weed biomass (5% or less) when soybean was maintained weed-free beyond the V3 soybean growth stage. Results shows that soybean must be maintained weed free up to the V3 growth stage for optimum yield. Weeds emerging after the V3 soybean growth stage did not influence the yield of glyphosate-resistant soybean.

SOYBEAN YIELD AS AFFECTED BY PLANTING DATE AND SEED TREATMENT. Kelsey Bergman*1, Brent Heaton2, Mark Bernards1; 1Western Illinois University, Macomb, IL, 2Western Illinois University, Industry, IL (83)

Recent research suggests soybean (Glycine max) yield will benefit from early planting. Reasons for the increased yield include more nodes plant-1, more pods plant-1, and more days of reproductive growth. Treated seeds are now becoming the standard for many soybean fields. The benefit of treated seeds is expected to be greatest for the early planted soybeans. Our hypotheses included: 1) soybean yield will decline when soybean planting is delayed past May 1, and 2) soybean seed treatment will increase soybean yield when soybean is planted before May 1. Our objectives were to measure the effect of 1) soybean planting date and 2) seed treatment on soybean stand, growth stage, and yield. This study was located at the WIU Agricultural Field Laboratory in Macomb, IL. The experiment was arranged in a randomized complete block design with four replications. The soils in the study area included an Ipava Silt Loam (south two replications) and a Sable Silty Clay (north two replications). Treatments were a factorial of soybean variety, seed treatment and planting date. Two soybean varieties, Nutech 3386L and 3321L, were planted at 346,000 seeds ha-1 into no-till corn stubble on six dates: April 12, April 25, May 9, May 22, June 7, and July 3. Each variety was planted without and with a seed treatment (Smart Cote Extra: imidacloprid, 600 g L-1 + prothionconazole, 76.8 g L-1 + penflufen 38.4 g L-1 + metalaxyl, 61.4 g L-1 + oxathiapiprolin, 200 g L-1). Plots were 1.5 x 39 m, and varieties were paired (with or without seed treatment) in adjacent plots within a planting date. Plots were treated with herbicides as needed to be maintained weed free. Stand counts were made following full emergence after each planting date. Soybean growth stage was measured regularly at five locations within a plot to analyze how planting date affected the length of each reproductive stage. Yield was measured using a plot combine, and harvest weights were adjusted to 13% to calculate yield. Because the earlier planted soybeans were very dry during harvest there was a large amount of shattering. Harvest loss was measured for each plant and the estimated loss was added to the measured yield. Rainfall during planting on May 22 created unfavorable conditions for seedling emergence and average stand counts were less than 124,000 seeds ha-1. Consequently, yield data for May 22 was inconsistently low compared to the May 9 and June 7 planting dates. Soybean yield declined when planting was delayed past April 25. Seed treatment had no effect on soybean yield.

EFFECT OF SOIL-APPLIED SULFENTRAZONE AND FLUMIOXAZIN ON SOYBEAN SEEDLING DISEASE SEVERITY UNDER FIELD CONDITIONS. Nicholas J. Arneson*, Loren J. Giesler, Rodrigo Werle; University of Nebraska-Lincoln, Lincoln, NE (84)

Weed management in soybean continues to be a challenge as many weed species have evolved resistance to multiple common herbicide modes of action. Herbicides with soil residual activity such as protoporphyrinogen oxidase inhibitors (PPOs) are now common inputs for weed management but can result in soybean seedling injury if the right environmental conditions occur during crop emergence. These conditions are also favorable for infection by fungal pathogens such as Fusarium spp., Rhizoctonia solani, and Pythium spp., which can have measurable impacts on crop stand and yield. In 2017, a field study was conducted at five locations in Nebraska (Auburn, Lincoln, Mead, Ord, and Tekamah) to determine the effect of PPOs on soybean seedling disease severity and grain yield. Experimental design was a randomized complete block design with a 2 x 3 x 2 factorial that included: i) two soybean cultivars (sensitive and tolerant to sulfentrazone), ii) three herbicide programs [glyphosate (GLY), sulfentrazone + GLY tank mixture, and flumioxazin + GLY tank mixture], and iii) two seed treatments (with and without fungicide) with four replications at each site. The sulfentrazone sensitive cultivar had 5-8% increase in root rot severity compared to the tolerant at Auburn and Tekamah ($P<0.05$). At Lincoln, there was a herbicide-cultivar interaction ($P<0.01$). In the tolerant cultivar, flumioxazin resulted in 6% increase in root rot severity compared to glyphosate ($P<0.01$). In the sensitive cultivar, sulfentrazone resulted in 4% decrease compared to glyphosate ($P<0.01$). At Mead, there was a herbicide-seed treatment interaction ($P<0.05$). With no seed treatment, sulfentrazone resulted in 10% decrease in root rot severity compared to glyphosate ($P<0.05$). At Tekamah, glyphosate treatment yielded nearly 480 kg/ha more than the PPOs ($P<0.05$). The fungicide seed treatment increased yields in 134-269 kg/ha at Auburn and Ord ($P<0.05$). Overall, different soil treated with PPO herbicides appear to have varying effects on root rot severity in soybeans but the impacts on yield are unclear. As producers continue to rely on soil applied herbicides for weed management, further investigations studying PPO herbicide interactions with varying disease pressure and environmental conditions are needed to understand their potential effects on yield.

THE INTERACTIVE EFFECTS OF SOYBEAN SENSITIVITY TO PPO-INHIBITING HEBICIDES, SEED TREATMENT, AND SEEDING RATE ON YIELD AND DISEASE. Rhett Stolte*1, Ahmad M. Fakhoury2, Jason P. Bond2, Karla Gage1; 1Southern Illinois University, Carbondale, IL, 2Plant Pathologist, Carbondale, IL (85)

A two-year field study was established in Shawneetown, IL to evaluate grain yield and disease potential of soybean cultivars which are either sensitive or tolerant to protoporphyrinogen oxidase (PPO)-inhibitor herbicides, with seed either treated with Upshot (insecticide + fungicide) and Avonni (biological fungicide) or non-treated, and planted at six different seeding rates 197,684, 247,105, 296,526, 345,947, 395,368, 444,789, and the controls were planted at a density of 345,947 seeds ha-1, for a 2 x 2 x 7 factorial study design. The purpose of this study was to evaluate effects of PPO-inhibiting herbicide treatment on Sudden Death Syndrome disease incidence and severity in soybean, and how disease incidence and severity related to stand count and grain yield in various population densities. The premise of the study was that PPO-inhibitor injury to soybean may stimulate the upregulation of Systemic Acquired Resistance (SAR) and cause plants to be less susceptible to other stressors, such as disease. Plots were planted on 4/25/2016 and 5/6/2017 in four-row plots measuring three m by seven m, and herbicide was applied to treated plots over the center two rows. Data collection included stand counts at 14 and 28 d after treatment (DAT), plant heights at end-of-season (EOS), and disease incidence and severity ratings beginning at the onset of symptomology. Lastly, grain yield was collected from the center two treated rows. All plots except the non-treated controls received an application of sulfentrazone + cloransulam-methyl (316 g ai ha-1). There were differences in stand count by seeding rate and seed variety at 17 and 28 DAT, but no interactive effects between the factors in 2016; however, in 2017, there were differences in stand count by seeding rate and seed treatment at 14 and 28 DAT, but once again, no interactive effects between factors. Relationships between stand count and seeding rate indicated a threshold at which the environment cannot sustain higher planting densities. Environmental conditions were more favorable in 2016 than 2017. Rainfall 10 days following planting was recorded at 67 mm and 290 mm in 2016 and 2017, respectively. Disease incidence (scale of 0 to 100%) in 2016 ranged from 0.75 up to 2.35 across rating dates, while severity (scale of 0 to 9 based on leaf symptomology) ranged from 0.8 to 2.1 across rating dates. In 2017 disease incidence ranged from 1.0 to 2.075 across rating dates. Disease severity ranged from 1.0 to 2.2 across rating dates. This indicates that the incidence was greater than severity across both years. Grain yield in 2016 ranged anywhere from 3,652.32 kg ha-1 up to 3,942.49 kg ha-1 with the highest grain yield in the sulfentrazone-tolerant variety and the lowest in the sulfentrazone-sensitive variety. In 2017, yield was lowest in the 197,684 plants ha-1 treatments at 2,309.44 kg ha-1 and highest in the 444,789 plants ha-1 treatments at 3,466.35 kg ha-1, and also had varietal differences and seed treatment differences. Disease was more prominent in the high-density plots than in the low-density plots, as would be expected, because of the effects of competitive stress on plant pathogen susceptibility. Grain yield was higher in the sulfentrazone-tolerant plots than in the sulfentrazone-sensitive plots as expected, as well as in the plots with treated seed. This yield increase is attributed to the early-season seedling diseases which are suppressed by the seed treatment in comparison to non-treated seed. Future and ongoing lab work will examine the potential for sulfentrazone to upregulate SAR.

IMPACT OF SOIL-APPLIED PPO AND PSII HERBICIDES ON EARLY SEASON SOYBEAN AND PALMER AMARANTH DEVELOPMENT. Nikola Arsenijevic*1, Matheus de-Avellar1, Liberty Butts2, Rodrigo Werle3; 1University of Nebraska-Lincoln, North Platte, NE, 2University of Nebraska Lincoln, North Platte, NE, 3University of Nebraska-Lincoln, Lincoln, NE (86)

Palmer amaranth has become a troublesome weed in row crop production across the US. This weed has evolved resistance to several herbicide modes of action; thus, the use of soil-applied herbicides has become crucial for proper management. The use of soil-applied herbicides at planting may also impact early season crop development. The objective of this study was to evaluate the impact of soil-applied herbicides on early season soybean development and Palmer amaranth control. The study was conducted near McCook (2016 and 2017) and Culbertson (2017), NE. Treatments consisted of metribuzin and sulfentrazone applied at their label rates (560 and 280 g ai ha-1) and also 1/3 and 2/3 of the label rates (six treatments). Moreover, metribuzin and sulfentrazone were mixed at all possible combinations of their full, 1/3 and 2/3 label rates (nine treatments). A control plot (no herbicide) was included for a total of 16 treatments. Herbicide treatments were applied up to three d after planting. Experimental plots consisted of four rows (three m wide) with 12 m in length replicated four times and in a randomized complete block design. Plots were divided into two 6-m segments; the first segment was kept weed-free and soybeans were evaluated at V2 growth stage by randomly placing four quadrats (76 x 76 cm) in second and third row and taking pictures of the demarked areas. Pictures were processed using the Canopeo app, which estimates live green vegetation (%). In the second segment, Palmer amaranth plants were allowed to grow and sampled for biomass estimation when soybeans reached R1 growth stage. The impact of soil-applied herbicides on early season soybean development was site-specific (e.g., different varieties and weather conditions at each site-year). Overall, results indicate that metribuzin, especially at higher rates, reduced early season soybean growth more than sulfentrazone. Soil-applied herbicides reduced Palmer amaranth biomass at R1 growth stage with sulfentrazone or the mixture of sulfentrazone plus metribuzin being more effective than metribuzin alone, regardless of rate. Yield data were also collected. Soil-applied herbicides are an important tool for management of Palmer amaranth; however, some may cause reduction on early season soybean growth.

WHAT'S IN YOUR BIRD FEEDER? SCREENING COMMERCIAL BIRD FEED MIXES FOR VIABLE WEED SEED CONTAMINANTS. Eric Oseland*1, Mandy Bish2, Kevin W Bradley2; 1University of Missouri, Columbia, IL, 2University of Missouri, Columbia, MO (87)

Troublesome weeds such as Palmer amaranth continue to invade new geographies in the US each year. Commercial bird feed mixes are comprised of various seed that are under no federal regulations for weed seed contamination. Most bags of commercial bird feed contain mixes of seeds from many different agricultural fields, and often from different regions of the US. In 2016 and 2017, 60 bags of commercially available bird feed from 22 companies were examined for the presence of weed seed. All weed seed contaminants were removed, counted, identified by species and stored for future analysis. Results indicate that Amaranthus species were present in 57 of the 60 bags of bird feed examined, at amounts ranging from 1 to 6,512 Amaranthus seed kg-1 of bird feed. Amaranthus species present in bird feed mixes include waterhemp (Amaranthus tuberculatus (Moq.) Sauer), redroot pigweed (Amaranthus retroflexus L.), Palmer amaranth (Amaranthus palmeri S. Wats), and tumble pigweed (Amaranthus albus L.). Palmer amaranth was present in 18 of the mixes screened. Seed of common ragweed (Ambrosia artemisiifolia L.), kochia (Bassia scoparia), shattercane [Sorghum bicolor (L.) Moench ssp. arundinaceium (Desy) de Wet & Harlan], wild buckwheat (Polygonum convolvulus L.), large crabgrass (Digitaria sanguinalis) and foxtail species (Setaria spp.) were also found in the bird feed mixes. A greenhouse assay to determine weed seed viability and resistance to glyphosate was performed after weed seed extraction. A discriminating dose of glyphosate at three times the labeled use rate was applied to Amaranthus species 5- to 10-cm in height to determine glyphosate resistance. Results from this assay indicate that approximately 41% of Amaranthus seed in bird feed mixes remain viable, and at least four mixes contained Amaranthus seed that were resistant to glyphosate. A stepwise regression was performed using SAS PROC REG to analyze ingredient effects on Amaranthus abundance in bird feed mixtures. The most predictive single ingredient that resulted in increases in Amaranthus species abundance was pearl millet followed by milo, nyjer thistle, and corn. Additional statistical analysis indicated that bird feed mixes that contained milo, millet, corn, and sunflower all contained a larger number of Amaranthus species than mixes that did not contain these ingredients. Results from this study will provide quantitative data about the potential involvement of commercial bird feed in the spread of economically important weed seeds throughout the US.

CHARACTERIZATION OF A PALMER AMARANTH POPULATION WITH REDUCED SENSITIVITY TO PPO-INHIBITING HERBICIDES AND LACKING KNOWN TARGET SITE MUTATIONS. Hailey B. Holcomb*1, Haozhen Nie1, Julie M. Young2, Bryan G. Young1; 1Purdue University, West Lafayette, IN, 2Purdue University, WEST LAFAYETTE, IN (88)

Palmer amaranth (Amaranthus palmeri) continues to present weed management challenges across a wide geography in the US. As of now, Palmer amaranth has evolved resistance to six different sites of action: HPPD-, PSII-, ALS-, microtubule-, EPSPS-, and PPO-inhibiting herbicides. Resistance to PPO-inhibiting herbicides has been attributed to the loss of glycine at position 210 or a substitution at position 98 of the PPO enzyme encoded by the PPX2L gene. Annually, putative resistant populations of Palmer amaranth are screened as a service to the crop production industry. In 2016 this screening effort identified a population of Palmer amaranth from Alabama (AL) that survived multiple applications of PPO-inhibiting herbicides in the field, but had a very low frequency (3%) of plants with the G210 deletion. Further investigation failed to identify plants with the R98 substitution. Herbicide dose response experiments were conducted in the greenhouse to evaluate the response of the AL population to fomesafen in comparison to known susceptible and resistant (via G210 deletion) populations to PPO-inhibiting herbicides. The GR50 values for the known susceptible, known resistant (G210), and AL population were 2.96, 6.24, and 9.37 g ai ha-1, respectively; and GR90 values of 329, 2,649, and 2,068 g ha-1, respectively. Resistance ratios for the known resistant and AL populations were 2.1 and 3.2, respectively, using the GR50 values and 8.1 and 6.3 using the GR90 values. Thus, the AL Palmer amaranth population exhibits resistance to PPO-inhibiting herbicides and contains a resistance mechanism other than the G210 or R98 target site mutations that have been confirmed to date.

CONFIRMATION OF A COMMON WATERHEMP BIOTYPE RESISTANT TO PROTOPORPHYRINOGEN OXIDASE (PPO) INHIBITORS IN NEBRASKA. Trey Stephens*, Debalin Sarangi, Amit J. Jhala; University of Nebraska-Lincoln, Lincoln, NE (89)

Common waterhemp (Amaranthus rudis Sauer) is the most problematic weed in corn (Zea mays L.) and soybean [Glycine max (L.) Merr] production fields in Nebraska. Recently, a common waterhemp biotype (NER) was identified in Saunders County, NE, that survived the POST application of lactofen, a protoporphyrinogen oxidase (PPO)-inhibiting herbicide. Whole-plant dose-response bioassays were conducted in the greenhouse to quantify the response of NER to acifluorfen, fomesafen, and lactofen. Two known PPO inhibitor-sensitive common waterhemp biotypes (S1 and S2) from Nebraska and one confirmed resistant biotype (ILR) from Illinois were included to compare the response of NER. Treatments included eight doses of PPO-inhibiting herbicides (0 to 16 x, where 1 x = labeled herbicide doses) and the biologically effective doses (ED50, ED70, ED80, and ED90; doses required to control common waterhemp biotypes by 50, 70, 80 and 90%, respectively) were determined using a four-parameter log-logistic function in R. Dose-response bioassay revealed that the NER biotype was resistant to acifluorfen (4- to 5-fold), fomesafen (3- to 6-fold), and lactofen (5- to 6-fold) in comparison to the susceptible biotypes. The values of the ratio of NER-ED50 to ILR-ED50 were 0.6, 1.6, and 0.4 for acifluorfen, fomesafen, and lactofen, respectively. The root mean square error for the log-logistic model were ≤ 20.0 and the model efficiency coefficient values ranged between 0.7 to 0.9, indicating a good fit for the prediction models. The response of NER biotype to POST soybean herbicides was evaluated and compared with the response of S1 biotype in the greenhouse. Results of the POST herbicide efficacy study showed that the NER biotype had reduced sensitivity to acetolactate synthase (ALS)-inhibiting herbicides (chlorimuron-ethyl, imazethapyr, and chlorimuron-ethyl plus thifensulfuron-methyl) and glyphosate. Dicamba (DGA salt), glyphosate plus 2,4-D choline, and glufosinate provided ≥ 95% control of NER. This is the first reported PPO inhibitor-resistant common waterhemp biotype in Nebraska. Furthermore, this study also revealed a reduction in the number of POST herbicide options in glyphosate-resistant soybean to control PPO inhibitor-resistant common waterhemp.

HALAUXIFEN-METHYL, 2,4-D, DICAMBA, AND GLYPHOSATE TANK-MIXTURES EFFICACY ON BROADLEAF WEEDS. Marcelo Zimmer*1, Bryan G. Young1, Bill Johnson2; 1Purdue University, West Lafayette, IN, 2Purdue University, W Lafayette, IN (90)

Synthetic auxin herbicides such as 2,4-D and dicamba are often utilized to control broadleaf weeds in preplant burndown applications for soybeans. Halauxifen-methyl is a new synthetic auxin herbicide for broadleaf weed control in preplant burndown applications for corn, cotton, and soybeans at low use rates (5 g ae ha-1). Field experiments were conducted to evaluate the efficacy and weed control spectrum of halauxifen-methyl applied alone at 5 g ae ha-1, and in tank-mixtures with 2,4-D (560 g ae ha-1), dicamba (280 g ae ha-1), and glyphosate (560 g ae ha-1). Glyphosate-resistant (GR) horseweed was controlled at 35 d after treatment (DAT) with treatments containing either halauxifen-methyl or dicamba (86% to 97% control), while glyphosate, 2,4-D, and 2,4-D + glyphosate resulted in less GR horseweed control (9, 71, and 71% control, respectively). Common ragweed was controlled with halauxifen-methyl applied alone and in tank-mixtures (91 to 97% control) at 35 DAT, while glyphosate, 2,4-D, and dicamba alone, as well as 2,4-D + glyphosate and dicamba + glyphosate resulted in lower common ragweed control (48 to 81% control). Halauxifen-methyl and glyphosate alone resulted in poor giant ragweed control at 21 DAT (78 and 73% control, respectively). Tank-mixtures of halauxifen-methyl with 2,4-D, dicamba, or glyphosate controlled giant ragweed, ranging from 86% control for halauxifen-methyl + glyphosate to 98% control for halauxifen-methyl + 2,4-D + dicamba + glyphosate. All treatments controlled redroot pigweed, except halauxifen-methyl and dicamba alone (62 and 78% control, respectively). Tank-mixtures of halauxifen-methyl with dicamba, dicamba + glyphosate, 2,4-D + glyphosate, and 2,4-D + dicamba controlled redroot pigweed at 35 DAT (86 to 94% control). Halauxifen-methyl controls GR horseweed and common ragweed applied alone and in tank-mixtures with other synthetic auxin herbicides and glyphosate. The addition of 2,4-D or dicamba with halauxifen-methyl is necessary to increase the weed control spectrum of halauxifen-methyl in preplant burndown applications.

FIERCE MTZ: A NEW PREEMERGENCE SOYBEAN HERBICIDE. Eric J. Ott*1, John A. Pawlak2, Dawn E. Refsell3, Ron E. Estes4, Jon R. Kohrt5, Lowell D. Sandell6, Trevor D. Israel7; 1Valent USA LLC, Greenfield, IN, 2Valent USA LLC, Lansing, MI, 3Valent USA LLC, Lathrop, MO, 4Valent USA LLC, Tolono, IL, 5Valent USA LLC, West Des Moines, IA, 6Valent USA LLC, Lincoln, NE, 7Valent USA LLC, Souix Falls, SD (91)

The combination of flumioxazin + pyroxasulfone (Fierce® 76 WG) and metribuzin (Mauler® 4L) are the components of a new soybean preemergence herbicide (Fierce® MTZ co-pack) for the 2018 growing season. The majority of the soybean herbicides available tod only contain one or two effective sites of action. Fierce® MTZ co-pack consists of three for control of problematic weeds like the Amaranthus species that have spread throughout the Midwest. The standard use rate of Fierce® MTZ (flumioxazin 70 g ai ha-1 + pyroxasulfone 90 g ai ha-1 + metribuzin 210 g ai ha-1) has been shown in research trials throughout the US to provide greater control of the larger seeded broadleaves such as velvetleaf, common ragweed, and common lambsquarters, compared to flumioxazin 70 g ai ha-1 + pyroxasulfone 90 g ai ha-1 at 56 DAT. Greater control of waterhemp, Palmer amaranth, common ragweed, common lambsquarters, and giant foxtail at 56 DAT has also been observed with the flumioxazin + pyroxasulfone + metribuzin compared to sufentrazone + metribuzin, as well as, greater ivyleaf morningglory and velvetleaf control than s-metolachlor + meribuzin. These results show that flumioxaxin + pyroxasulfone + metribuzin can provide residual control of a broad spectrum of problematic weed species well into the growing season.

EFFICACY OF TAVIUM™ HERBICIDE PLUS VAPORGRIP® TECHNOLOGY IN DICAMBA-TOLERANT SOYBEANS AND COTTON. Scott A. Payne*1, Brett Miller2, James C. Holloway3, Erin M. Hitchner4, Donald J. Porter5; 1Syngenta, Slater, IA, 2Syngenta, Minnetonka, MN, 3Syngenta, Jackson, TN, 4Syngenta, Elmer, NJ, 5Syngenta, Greensboro, NC (92)

Tavium Plus VaporGrip Technology is a new herbicide under development by Syngenta for use in dicamba-tolerant soybeans and cotton. It is a pre-mixture containing three key components: dicamba (a group 4 herbicide), s-metolachlor (a Group 15 herbicide), and VaporGrip Technology which decreases the volatility of dicamba and reduces the chance for off-site movement. Tavium Plus VaporGrip Technology provides postemergence control of over 50 broadleaf weeds as well as extended residual control of key broadleaf weeds such as waterhemp and Palmer amaranth and troublesome grasses. Tavium Plus VaporGrip Technology offers flexibility in application timing by allowing one application from preplant burndown through preemergence and one application postemergence in both dicamba-tolerant cotton and soybeans. By employing two modes of action, Tavium Plus VaporGrip Technology is an effective resistance management tool which will fit well into an integrated weed management program by delivering postemergence control and enabling overlapping residual activity.

CONTROL OF VOLUNTEER GLYPHOSATE-TOLERANT ALFALFA IN NO-TILL ROUNDUP READY XTEND SOYBEAN. Lisa M. Behnken*1, Fritz Breitenbach2, Annette Kyllo1; 1University of Minnesota Extension, Rochester, MN, 2Univ of Minn Extension, Rochester, MN (93)

The most effective and recommended method of terminating an alfalfa (Medicago sativa L) stand is a combination of herbicides and tillage in the fall prior to planting the next crop. Even with fall termination, alfalfa can become a weed in the following crop. Spring termination of an alfalfa stand due to planned rotation or winter injury can increase the probability of volunteer alfalfa in the subsequent crop. Volunteer alfalfa is more difficult to control if it is glyphosate-tolerant. Many times corn is the preferred crop to plant in rotation after alfalfa. If volunteer alfalfa becomes a problem in corn, a common recommendation is to use an herbicide with dicamba to control it. There are times when planting corn after winter kill, injured or spring terminated alfalfa stand is not feasible. Soybeans can be an option for the following crop, which accommodates time needed to assess alfalfa stands and perhaps harvest the remaining forage before terminating. There are few effective herbicide choices for controlling glyphosate-tolerant alfalfa in soybeans. Some herbicides will suppress the alfalfa and reduce competition, but effective control in soybeans is difficult. Ddicamba-tolerant soybeans along with new dicamba formulations are now available to growers. This technology provides growers an additional herbicide choice for controlling volunteer glyphosate-tolerant alfalfa in soybeans. The objective of this trial was to evaluate, compare and demonstrate the effectiveness of dicamba based systems for controlling volunteer glyphosate-tolerant alfalfa in no-till soybeans in southeastern Minnesota. A three-year old glyphosate-tolerant alfalfa stand was mowed several times in the spring to suppress the alfalfa prior to planting and to provide volunteer alfalfa competition. Soybeans were no-till planted in 75-cm rows at a rate of 408,000 seeds hectare-1. A randomized complete block design with three replications was used. Six treatments were compared and applied at: A) shortly after planting, B) 10-cm tall alfalfa, C and D) 10-cm tall alfalfa regrowth. The treatments were, A, glyphosate; A, fomesafen + glyphosate / C, glyphosate + chloransulam-methyl; A, sulfentrazone + chloransulam-methyl / C, fomesafen + glyphosate; A, dicamba + glyphosate / D, dicamba + glyphosate; B, dicamba + glyphosate / D, glyphosate; and A, dicamba + glyphosate. Evaluations were collected from July through October. Dicamba systems provided greater than 90% control of volunteer alfalfa compared to 60-65% for the systems without dicamba. This shows that genetically modified soybean resistant to glyphosate and dicamba offers a new management strategy for controlling volunteer alfalfa in soybeans.

COMPARISONS OF WEED MANAGEMENT INTENSITY LEVELS UTILIZING ROUNDUP READY XTEND AND LIBERTYLINK SOYBEAN. Damian Franzenburg*1, M D K Owen2, James Lee2, Iththiphonh Macvilay2; 1Iowa State Univesity, Ames, IA, 2Iowa State University, Ames, IA (94)

The objective of this research was to evaluate several levels of herbicide management by increasing the number and timing of residual herbicides. Experiments were conducted in two tillage systems and two herbicide-tolerant soybean varieties at sites near Ames, Nashua, and Lewis, IA in 2017. Reduced-tillage methods were used at Ames and Nashua experiments and no-tillage was used at the Lewis experiment. The experimental design was split-plot including soybean variety as whole plots and herbicide management intensity as split-plots with four replications. Soybean 'Asgrow AG24X7' and 'LG C2427LL' were planted on 76-cm row spacings on corn ground. Plots were 3 by 7.6 m. Treatments included early preplant (EPP) in no-tillage or preemergence (PRE) in reduced tillage followed by postemergence (POST) applications applied to soybean at V2 to V3 in conventional studies and V4 for the no-tillage study. Weed heights were 5 to 12.5 and 30 cm tall for the two conventional and no-tillage study, respectively. Treatments for dicamba-tolerant soybean in the reduced tillage experiments included PRE flumioxazin, flumioxazin + dicamba, and flumioxazin + dicamba followed by POST dicamba + glyphosate, dicamba + glyphosate and dicamba + acetochlor + glyphosate, respectively. The no-tillage dicamba-tolerant soybean study included EPP dicamba + glyphosate, flumioxazin + dicamba + glyphosate, and flumioxazin + dicamba + glyphosate followed by POST dicamba + glyphosate, dicamba + glyphosate, and acetochlor + dicamba + glyphosate. Treatments for glufosinate-tolerant soybean in reduced-tillage included PRE flumioxazin, sulfentrazone + chlorimuron-ethyl and sulfentrazone + chlorimuron-ethyl followed by glufosinate, glufosinate and pyroxasulfone + glufosinate, respectively. The no-tillage glufosinate-tolerant soybean treatments included EPP 2,4-D + glyphosate, sulfentrazone + chlorimuron-ethyl + 2,4-D + glyphosate, and sulfentrazone + chlorimuron-ethyl + 2,4-D + glyphosate followed by POST glufosinate, glufosinate and pyroxasulfone + fluthiacet-methyl + glufosinate, respectively. All glyphosate + dicamba treatments contained 0.5% v v-1 guar gum, and glufosinate treatments contained 0.01 kg L-1 ammonium sulfate. An untreated control for each soybean variety whole plot was also included with the treatments. Weed control ratings at harvest and grain yield were collected. Weed control at harvest varied slightly between treatments applied to glufosinate-tolerant soybean. Common waterhemp control varied between treatments planted to glufosinate-tolerant soybean for the reduced-tillage experiment at Nashua (95, 90 and 98% control) and the no-tillage experiment at Lewis (75, 99 and 99% control) with increased inclusion of residual herbicides to treatments. For the reduced tillage study at Nashua, giant foxtail control was improved when glufosinate was tank-mixed with pyroxasulfone. Velvetleaf control in reduced tillage varied between treatments only at the Ames location. All treatments provided at least 96% control. There were no differences in weed control between dicamba treatments. Treatments with glyphosate + dicamba provided at least 96% control of weeds evaluated. Treatments with POST glufosinate + pyroxasulfone and POST glufosinate + sulfentrazone + chlorimuron-ethyl provided similar control to dicamba treatments. Reduced common waterhemp control came from PRE flumioxazin followed by POST glufosinate (though still providing 96% control), PRE sulfentrazone & chlorimuron-ethyl followed by POST glufosinate and EPP 2,4-D + glyphosate followed by POST glufosinate at Ames, Nashua and Lewis, respectively. The PRE sulfentrazone + chlorimuron-ethyl followed by POST glufosinate treatment also provided less giant foxtail control than most other treatments at Nashua. Yield differences were only observed in Ames between PRE flumioxazin followed by glufosinate and PRE flumioxazin + dicamba followed by either POST dicamba + glyphosate or POST dicamba + glyphosate + acetochlor. The residual control characteristics of dicamba likely contributed to consistent weed control for dicamba-tolerant soybean treatments. Similar control could be achieved for each system with appropriate residual herbicide selection (e.g. a residual herbicide could be added to the 2,4-D + glyphosate no-tillage burndown treatment).

EFFICACY OF GLUFOSINATE AND DICAMBA TANK-MIXTURES ON COMMON LAMBSQUARTERS, PALMER AMARANTH, CORN, AND GRAIN SORGHUM. Milos Zaric*1, Karla A. Romero2, Jeffrey Golus1, Greg R Kruger3; 1University of Nebraska-Lincoln, North Platte, NE, 2University of Zamorano, Zamorano, Honduras, 3University of Nebraska, North Platte, NE (95)

Chenopodium album and Amaranthus palmeri are two of the most problematic weeds in crops such as corn and grain sorghum. Across the US, as tillage is reduced, the reliance on herbicides is increased. Dicamba is an important systemic herbicide used for broadleaf weed control. The use of different herbicides in tank-mixture with different modes of action, such as glufosinate and dicamba, can be considered as one of the strategies to suppress herbicide-resistant weeds. This mixture allows multiple mechanisms of action to be applied at the same time, expanding the weed control spectrum and potentially enhancing herbicides efficacy. The objective of this study was to evaluate the efficacy of tank-mixtures of glufosinate and dicamba on weed control (common lambsquarters, Palmer amaranth, corn (Zea mays), and grain sorghum (Sorghum bicolor (L.) Moench)) in a dose-response experiment with a factorial arrangement of treatments. The plants were grown in a greenhouse under controlled conditions and treated when they reached approximately 12 cm in height. Each treatment had seven replications with an individual plant being considered as a single replication. The treatments were applied using a single nozzle track sprayer with a TeeJet AI95015EVS nozzle calibrated to deliver 140 L ha-1 at 345 kPa pressure. Two separate trials were conducted in a randomized complete design with 49 different tank-mixtures of glufosinate and dicamba. Concentrations of glufosinate and dicamba (0, 0.25, 0.5, 1, 2, 4, and 8X) were applied in all combinations, where 1X of glufosinate and dicamba were 1120 and 280 g ae ha^{-1}, respectively. Plant injury was visually estimated at four wk after treatment. Above ground biomass was recorded 28 d after treatment, plants were dried at 65 C to constant weight. The biomass data were converted into a percentage of biomass reduction as compared to the untreated control. Data were fitted with a non-linear regression model with the drc package in R software. The GR50 and GR90 values were estimated for each dicamba and glufosinate combination in all weed species using a four parameter log logistic equation: y=c+{d–c/1+exp[b(logx–loge)]}, where y corresponds to the biomass reduction, b is the slope at the inflection point, c is the lower limit, d is the upper limit, and e is the GR50 parameter. Results indicate that there was no evident antagonistic effect of dicamba and glufosinate tank-mixtures on weeds control. Glufosinate GR50 estimations for sorghum ranged from 393 (no dicamba in the solution) to 380 g ae ha-1 (2X Dicamba in the solution). The same trend was observed for corn, where glufosinate GR50 estimations ranged from 1121 (no dicamba in the solution) to 980 g ae ha-1 (2X dicamba in the solution). Dicamba GR50 estimations for Palmer amaranth and common lambsquarters were decreased as glufosinate rates were increased in the tank solution. Additional studies are necessary to better understand the interactions between different herbicides in tank-mixtures, especially for those including dicamba since it has been reported that the herbicide antagonizes some herbicides such as clethodim.

WEED CONTROL WITH SELECTED DICAMBA TREATMENTS IN NORTHEAST NEBRASKA. Jon E Scott*1, Stevan Z. Knezevic2; 1University of Nebraska, Concord, NE, 2University of Nebraska-Lincoln, Concord, NE (96)

Weed resistance is increasing, therefore, the introduction of dicamba-tolerant soybeans could provide another option for weed control. Several studies were conducted in 2017 including no-till and conventional-till. The focus of the studies was to evaluate several soil residual herbicides and dicamba timings for weed control. In 2017 conventional-till preemergence treatments failed to provide weed control due to lack of activating rainfall. Early postemergence treatments of dicamba, glyphosate and a residual aided the control of green foxtail, velvetleaf and waterhemp, although control was not season long. Applying glyphosate and dicamba without or with residual herbicides at approximately 30 d after planting resulted in season-long weed control. Applications of dicamba in no-till before planting without or with a residual herbicide provided good control of horseweed. Waiting to apply dicamba in-season did not control horseweed that was over 50 cm tall. The potential to use dicamba to control various weed species in soybean exists. Repeated use of dicamba alone or in combination with glyphosate should be avoided to reduce the potential for dicamba resistance, as there is already dicamba-resistant kochia in western Nebraska.

SCHEDULED HERBICIDE APPLICATIONS AND MICRO-RATES FOR WEED MANAGEMENT IN DICAMBA-RESISTANT SOYBEAN. Nathan Hilleson*1, Brent Heaton2, Mark Bernards1; 1Western Illinois University, Macomb, IL, 2Western Illinois University, Industry, IL (97)

Micro-rate herbicide programs were developed for sugarbeets in the late 1990's to reduce crop injury from herbicides (Dexter and Leucke 1998). Three- or four-scheduled postemergence micro-rate herbicide applications were most effective when they followed a PRE herbicide application, and were equivalent to standard split applications (Dale et al. 2006; Odero et al. 2008; Robinson et al. 2013). Issues with herbicide-resistant weed populations in soybean demand exploring new approaches to weed control. Scheduled micro-rate herbicide applications targeted weeds that were small and more susceptible, and reduced total environmental herbicide load. Our objective was to compare weed control from scheduled herbicide applications at labeled rates with scheduled micro-rate applications. We predict that micro-rate herbicide programs in soybean will result in equivalent weed control to sequential PRE followed by POST herbicides using labeled-rates. Soybeans (AG36X6) were planted in 76-cm rows at 342,000 seeds ha-1 on 5/16/2017, at the Western Illinois University Agricultural Field Laboratory in Macomb, IL on a Sable silty clay loam. The experiment was arranged in randomized complete block design and was replicated four times. Each plot was 3 x 10.7 m. Herbicides were applied using a CO2 backpack sprayer with a four nozzle boom equipped with TTI11002 nozzles calibrated to apply 140 L ha-1. Treatments included a PRE-only, a POST-only, PRE followed by POST at different intervals (21, 28, and 35 days) and different rates (labeled, 75% and 50% of labeled), and a pair of micro-rate concepts with 10 or 14 day intervals between herbicide applications.Weeds present in the study area included waterhemp (Amaranthus tuberculatus), giant foxtail (Setaria faberi), morningglory (Ipomoea spp), cocklebur (Xanthum strumarium). Visual estimations of weed control were collected July 7. Weed counts in a 0.93 m2 quadrat were taken 7/21/2017. Weed biomass was collected prior to soybean harvest. Soybean grain was harvested using a plot combine from the middle two rows, and moisture was adjusted to 13%.

EVALUATION OF GLYPHOSATE-RESISTANT PALMER AMARANTH CONTROL WITH TWO-PASS PROGRAMS IN DICAMBA- AND GLUFOSINATE-TOLERANT SOYBEAN SYSTEMS. Colton P. Carmody*1, Karla Gage2, Ron Krausz3; 1Graduate Student, Carbondale, IL, 2Southern Illinois University, Carbondale, IL, 3Southern Illinois University, Belleville, IL (98)

Due to over-reliance of glyphosate as the sole herbicide site of action in weed management programs, the selection and rapid spread of glyphosate-resistant Amaranthus palmeri (Palmer amaranth) is impacting crop production across a wide geographical area. Widespread herbicide resistance to acetolactate synthase inhibitors, protoporphyrinogen oxidase inhibitors (PPO), and other herbicide sites of action, illustrate the ability of Palmer amaranth to rapidly adapt to management strategies. Currently, the use of glufosinate- or dicamba + glyphosate-resistant soybean systems may be the only reliable method available for controlling Palmer amaranth populations with multiple herbicide-resistance; therefore, it is critical to preserve the efficacy of available technologies. In a two-year study, field experiments were established near Collinsville, IL at a location where glyphosate- and PPO-resistant Palmer amaranth are present at high and low frequencies, respectively. Preemergence (PRE) followed by (fb) postemergence (POST) herbicide programs, as well as a POST-only programs were evaluated in two soybean systems: glufosinate- and dicamba + glyphosate-resistant soybean. Visual estimations of weed control were collected at 14 and 28 d after treatment (DAT). PRE herbicides were evaluated before POST herbicides were applied, and a separate analysis was conducted for PRE herbicide comparisons. At 28 DAT, there was no difference between PRE herbicides, with control ranging from 87-99%. Regardless of soybean system, year, or evaluation timing, there were no differences between PRE fb POST treatments, with 98% or higher Palmer amaranth control 28 DAT. In 2016, the POST-only application in dicamba + glyphosate-resistant soybean provided 93% control, while POST-only in glufosinate-resistant soybean provided 60% Palmer amaranth control 28 DAT. In 2017, there was no difference between POST-only applications, ranging from 80-86% control. The consistency of using PRE fb POST herbicide programs, regardless of soybean system, further supports the use of an efficient soil herbicide followed by a timely POST application. This data should provide growers effective management strategies to control multiple herbicide-resistant Palmer amaranth.

STRATEGIES FOR CONTROL OF PALMER AMARANTH THAT SURVIVED A POST CONTACT HERBICIDE. Jesse A. Haarmann*, Bryan G. Young, William G. Johnson; Purdue University, West Lafayette, IN (99)

Contact herbicides can fail to adequately control weeds in a variety of situations including unfavorable application conditions, inadequate herbicide rate and coverage, or herbicide resistance. Surviving weeds are typically more branched, stressed, and more difficult to control as a result of the first application. Choices for chemical control of these weeds are often limited by crop herbicide tolerance, crop growth stage, and calendar date. To determine the most effective herbicide choice and application timing to control Palmer amaranth escapes, a field trial was conducted in Indiana on Palmer amaranth in 2017. Plots were sprayed with a sub-lethal rate of either glufosinate or fomesafen to simulate a field situation of herbicide failure. Sequential treatments of glufosinate at 450 and 740 g ai ha-1, fomesafen at 450 g ai ha-1, lactofen at 220 g ai ha-1, 2,4-D at 1120 g ae ha-1, and dicamba at 560 g ae ha-1 were made 4, 7, or 11 d after initial application. Palmer amaranth control was assessed by counting new branches on marked plants at one and two wk following each sequential herbicide application. After initial fomesafen application, all sequential herbicide treatments but fomesafen and lactofen applied four and seven d later reduced branches in comparison to no sequential herbicide. After initial glufosinate application, sequential herbicide treatments of glufosinate and fomesafen at all timings and 2,4-D at the 7 d timing had the highest reduction in branches. Dicamba, 2,4-D, and glufosinate at the low rate had 64 to 95% fewer branches when sequential treatment was applied 7 d after initial application compared to 11 d after initial application. Lactofen and fomesafen had 13 to 55 % fewer branches when sequential treatment was applied 11 d after initial application compared to 3 d after initial application. Across all treatment timings, glufosinate 2,4-D, and dicamba resulted in greater control than fomesafen and lactofen when fomesafen was the initial application. Glufosinate and fomesafen resulted in greater control than 2,4-D, dicamba and lactofen when glufosinate was the initial application.

EVALUATION OF &LDQUO;RECOVERY&RDQUO; TREATMENTS FOR DICAMBA-INJURED SOYBEAN. Shea Farrell*, Mandy Bish, Kevin W Bradley; University of Missouri, Columbia, MO (100)

Incidences of off-target dicamba movement in 2017 resulted in injury to an estimated 1.5 million hectares of non-dicamba-tolerant (non-DT) soybean across the US. The off-target dicamba movement and subsequent injury has resulted in many questions regarding the ability of non-DT soybean to recover without yield loss. A field experiment was conducted in 2017 in Missouri to determine if yield-promoting tactics in soybean could influence recovery of non-DT soybean injured by dicamba. The experiment was conducted in a randomized complete block design. Each treatment was replicated six times. A single application of dicamba at 1/100th of the labeled use rate (5.6 g ae ha-1) was applied to non-DT soybean at the V3-V4 or R1-R2 stages of growth. Each of 10 different yield-promoting treatments were applied 14 d following the dicamba application; recovery treatments included: PercPlus, Megafol, Ele-Max Hi-Phos, a combination of Megafol and Ele-Max Hi-Phos, YieldOn, Awaken, Radiate, Priaxor, urea with agrotain and irrigation. A non-herbicide treatment and a dicamba treatment without a corresponding recovery treatment were included as controls at each growth stage. Visual soybean injury was assessed 7 and 21 d after application (DAA) of recovery treatments. Across recovery tactics, plants treated with dicamba at the V3 stage displayed 25% visual injury seven DAA. Each recovery tactic utilized on plants injured at the V3 growth stage were similar to the dicamba-injured control plants except for plants treated with Awaken supplement, which resulted in 23% injury compared to dicamba-injured soybean. Across recovery tactics, plants treated with dicamba at the R1-R2 growth stage exhibited 32% injury. Each recovery tactic utilized on plants injured at the R1-R2 growth stage resulted in soybean injury levels similar to or higher than the dicamba-injured control plants. Irrigation was the only recovery tactic that resulted in higher yields than the dicamba-injured control soybean across growth stages. Irrigation to plants injured at the V3-V4 and R1-R2 growth stages resulted in 206 and 389 kg ha-1 higher yields than the dicamba-injured controls, respectively. These preliminary results indicate that the yield-promoting tactics evaluated here, with the exception of irrigation, are likely not candidates for enhancing soybean recovery following dicamba injury.

UTILIZING GEOSPATIAL TECHNOLOGY TO ASSESS OFF-TARGET DICAMBA INJURY AND YIELD LOSS IN MISSOURI SOYBEAN FIELDS. Brian R. Dintelmann*, Shea Farrell, Kent Shannon, Mandy Bish, Kevin W Bradley; University of Missouri, Columbia, MO (101)

Off-target movement of dicamba was estimated to occur on approximately 40,000 and 130,000 hectares on non-dicamba tolerant (DT) soybean in Missouri in 2016 and 2017, respectively. In non-DT soybean, previous research has shown that injury and yield loss from dicamba is correlated with specific doses and stages of soybean growth. In field settings, practitioners never know the specific dose of dicamba that contacted the non-DT soybean. This makes it difficult, if not impossible, to predict yield loss. The objectives of this research were to determine if late-season dicamba injury evaluations can be used to predict yield loss on a field-scale level after off-target movement of dicamba has occurred. In 2016 and 2017, four non-DT soybean fields were assessed for dicamba injury using the scale set forth by Behrens and Lueschen (1979). Field sizes ranged from 14 to 48 ha. Field boundaries and grids were mapped in Ag Leader SMS software. Sample locations were established within each field using a center grid format at spacings of 25 m. Handheld GPS units were used to navigate to the predetermined grid locations and record visual estimations of soybean injury once soybean reached the R6-R7 stage of growth. Site-specific yield information was then obtained through combine yield monitors. Soybean yield and injury ratings at each predetermined sample location were compared in SAS using the MEANS procedure at $\alpha = 0.05$. Visual estimations of injury were grouped to estimate yield loss ranges based on the MEANS procedure and results were then compared back to actual yields. In addition, georeferenced yield was compared to previous field averages to define changes in percent yield of the historic average. Results from 2016 indicate that historically, yield loss did not occur until at least 20% visual injury was observed and >25% yield loss occurred when at least 40% injury was observed. Estimated yield losses based on in-season visual injury ratings were within 2.5% of the actual yield across all four fields assessed in 2016. Results from this research will help farmers and agriculture professionals to better understand the effects that off-target movement of dicamba can have on soybean yield.

IMPACT OF SIMULATED DICAMBA DRIFT ON SENSITIVE SOYBEAN. Jerri Lynn Henry*, Reid Smeda; University of Missouri, Columbia, MO (102)

In the face of increasing multiple herbicide resistant species, grower adoption of dicamba-tolerant (DT) soybeans occurred on 22% of soybean hectares in 2017. Reports of off-target injury to adjacent soybeans emphasized the sensitivity of non-DT soybeans to dicamba. Field research in Missouri was initiated to correlate dicamba concentrations to soybean height and crop yield. Applications of various concentrations of dicamba (diglycolamine salt) were made to V3 (0 to 250 ppm) and R1 (0 to 150 ppm) soybeans. Canopy heights were recorded between 7 and 28 d after treatment (DAT). At 21 DAT, plant height was inversely correlated at both V3 ($R2 = 0.9114$) and R1 ($R2 = 0.8355$), with up to a 50 and 33% decrease in plant height for V3 and R1 soybean, respectively. At 150 ppm, crop yields were reduced by 13 and 20% at V3 and R1, respectively. Canopy height was incrementally reduced by dicamba, with measurable reductions at concentrations as low as 10 ppm. Reductions in soybean yield required concentrations above 100 ppm for V3 applications and 45 ppm for R1 applications. Previous work at the University of Missouri reported that spray tank rinsate can contain up to 100 ppm dicamba after tank cleanout. Results emphasize the need to reduce dicamba-sensitive soybean to dicamba, especially during early flowering.

GLYPHOSATE-RESISTANT SOYBEAN RESPONSE TO SEQUENTIAL APPLICATIONS OF DICAMBA AND OTHER POSTEMERGENCE HERBICIDES. Nicholas C. Hayden*, William G. Johnson, Bryan G. Young; Purdue University, West Lafayette, IN (103)

The recent commercialization of dicamba-resistant soybeans has led to an increase in dicamba applications and a longer period throughout the growing season for these applications to occur. This shift to new technology has increased the potential for injury to dicamba sensitive soybeans through tank contamination or off-target movement of dicamba. Even with improved formulations of dicamba and increased label restrictions for applying dicamba, the widespread off-target injury to sensitive soybeans was a major concern during the 2017 growing season. Current postemergence herbicide options for soybean may include herbicides such as lactofen, acetochlor, chlorimuron, and/or 2,4-DB which may also injure soybean from direct applications and influence the extent of soybean injury from accidental dicamba exposure that occurs prior to or following those herbicides. Thus, a field experiment was conducted at the Throckmorton Purdue Agricultural Center near Lafayette, IN to evaluate the combined influence of other postemergence herbicides along with accidental exposure to dicamba on soybean injury and yield. Glyphosate, lactofen, chlorimuron, lactofen with acetochlor, and lactofen with 2,4-DB were applied at both the V3 and R1 growth stages of soybean. A reduced rate of dicamba (5.6 g ae ha-1) was applied at R1 following the other herbicides applied at V3, or dicamba was applied at V3 prior to the other herbicides applied at R1. This reduced rate was intended to simulate a dose representing off-target exposure to soybeans. Evaluations included visual estimates of plant injury, plant height, growth stage, and the Behrens and Lueschen scale at 14 and 28 d after treatment. Nodes plant-1, reproductive nodes plant-1, pods node-1, pods plant-1, 100 seed mass, and total mass were collected for 10 plants plot-1 at harvest, as well as plant height, soybean population, and grain yield for the center two rows of the four-row plots. When the combination of glyphosate, lactofen, and 2,4-DB was applied to soybean at the V3 growth stage the subsequent injury from dicamba exposure at R1 was greater than having no previous herbicide treatment or any of the other herbicide treatments applied on V3 soybean. When dicamba exposure occurred early in soybean growth at V3, the injury from a subsequent application of glyphosate plus lactofen or glyphosate plus lactofen and 2,4-DB on R1 soybean resulted in greater injury relative to no previous exposure to dicamba. The main factors that influenced soybean yield included dicamba and lactofen applications. Late exposure to dicamba at R1 reduced soybean yield by as much as 35%, whereas dicamba exposure at V3 resulted in less than a 10% reduction in soybean yield. Late applications containing lactofen reduced soybean yield compared with glyphosate only treatments. Thus, yield loss from late-season exposure to dicamba can be significant regardless of any injury from previous direct applications of POST herbicides. However, when soybean were exposed to dicamba earlier in the season (V3), the potential yield loss was driven primarily by the herbicide application made directly to soybean later in the season (R1). In other words, late-season applications of lactofen resulted in greater yield loss than early exposure of soybean to dicamba.

GROWTH AND DEVELOPMENT OF IRRIGATED GLYPHOSATE-TOLERANT SOYBEANS AS INFLUENCED BY MICRO-RATES OF CLARITY. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (104)

A field experiment was conducted in 2017 at Concord, NE to establish baseline data on the injury of potentially sensitive glyphosate-tolerant (GT) soybean to micro-rates of dicamba at three application times in irrigated system. The experiment was laid out in a split-plot design with six Clarity micro-rates (0, 1/10, 1/50, 1/100, 1/500, 1/1000 of the label rate (1 = 560 g ae ha-1)), three application times (2nd trifoliate (V2), 7th trifoliate/beginning of flowering (V7/R1), and full flowering (R2) growth stages) with four replications. Plots had four rows of GT soybean and were 10 m long by 3 m wide. Visual estimation of injury was recorded 7, 14, 21 and 28 d after treatment (DAT). Plant height, number of branches, d to flowering, number of flowering nodes, d to canopy closure, and d to physiological maturity were collected. Results showed that increase in dicamba dose reduced soybean height and delayed physiological maturity. Dicamba doses of 3.81-12.79 g ae ha-1 caused 50% reduction (10-25 cm) in plant height at 28 DAT across three application times. Reduction in plant height ultimately delayed soybean canopy closure, which can reduce soybean competiveness against weeds. Dicamba doses of 0.92-3.71 g ae ha-1 delayed physiological maturity by 10 to 15 d depending on the crop growth stage of dicamba application. A delayed maturity would not only delay harvest, it could also make the crop subject to frost damage. The V7/R1 stage was more sensitive to dicamba than the V2 and R2 stages. For example, 0.92 g ae ha-1 caused a 50% delay to maturity compared to 2.15 and 3.71 g ae ha-1 required for V2 and R2. In general, these results suggested that GT soybeans are sensitive to low rates of dicamba. Hence, off-target movement of dicamba must be prevented.

YIELD OF IRRIGATED GLYPHOSATE-TOLERANT SOYBEANS AS INFLUENCED BY MICRO-RATES OF CLARITY. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (105)

The overall goal of the project was to establish information on the potential injury of glyphosate-tolerant (GT) soybean to micro-rates of dicamba. The study was conducted in 2017 at Concord, NE, in a split-plot design with six dicamba rates, three application times and four replications. Dicamba micro-rates were: 0, 1/10, 1/50, 1/100, 1/500, and 1/1000 of the label rate (560 g ae ha-1). Plots had four rows of glyphosate-tolerant (GT) soybean and were 10 m long by 3 m wide. The three application times were 2nd trifoliate (V2), 7th trifoliate/beginning of flowering (V7/R1), and full flowering (R2) growth stages. Visual estimation of injury was recorded at 7, 14, 21 and 28 d after treatment (DAT). Yields of GT soybeans were also collected. Increase in dicamba dose increased soybean injury and reduced yield for all application times. Dicamba dose of 0.28-0.99 g ae ha-1 caused 50% soybean injury at 21 DAT depending on the application time. The V7/R1 stage was more sensitive to dicamba than the V2 and R2 stages based on injury at 21 DAT. The sizes of pods decreased with increased dicamba rate for V7/R1 and R2 timing. Dicamba doses of 11.63 to 26.63 g ae ha-1 reduced yield by 50% (275 to 1900 kg ha-1) depending on the crop growth stage of dicamba application. In terms of yield reduction, R2 was more sensitive to dicamba than the V2 and V7/R1 timings. For example, 11.63 g ae ha-1 caused a 50% reduction in soybean yield (1900 kg ha-1) at R2 stage, compared to 26.63 and 15.21 g ae ha-1 required at V2 and V7/R1 stage, respectively. Pod deformation and curling was more severe in R2 than earlier application timings (V7/R1 and V2). In general, off-target movement of dicamba must be prevented as these results suggest that GT soybeans were sensitive to low rates of dicamba.

YIELD OF DRYLAND GLYPHOSATE-TOLERANT, GLUFOSINATE-TOLERANT, AND CONVENTIONAL SOYBEANS AS INFLUENCED BY MICRO-RATES OF CLARITY. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (106)

A field study was conducted in 2017 to establish baseline data on the injury of potentially sensitive soybeans, including Conventional, Liberty-link (Glufosinate-tolerant), and Round-up Ready (Glyphosate-tolerant) soybeans to micro-rates of Clarity (dicamba) applied at different soybean growth stages in dryland system. Field experiments were conducted at concord, NE, as a split-split-plot design with 3 soybean types, 6 Clarity rates (0, 1/10, 1/50, 1/100, 1/500, 1/1000 of the label rate (560 g ae ha-1)), 3 application times (2nd trifoliate (V2), 7th trifoliate/beginning of flowering (V7/R1), and full flowering (R2) growth stages) and 4 replications. Increase in Clarity dose significantly increased soybean injury and reduced yield of all soybean types for the three application times. Clarity dose of 0.45-1.78 g ae ha-1caused 50% visual injury in Conventional soybean; 0.52-2.14 g ae ha-1 in Glufosinate-tolerant soybean; and 0.56-2.19 g ae ha-1 in Glyphosate-tolerant soybean across three application times. Clarity dose of 5.77-17.30 g ae ha-1 reduced yield by 50% (540 to 1825 kg ha-1) in Conventional soybean; 8.64-18.4 g ae ha-1 in Glufosinate-tolerant soybean; and 6.46-16.92 g ae ha-1 in Glyphosate-tolerant soybean depending on the crop growth stage of Clarity application. The V7/R1 was the most sensitive stage to Clarity when compared to V2 and R2 in Glufosinate- and Glyphosate-tolerant soybeans, based on yield reduction. Overall, R2 was less sensitive to Clarity compared to V2 and V7/R1 for all soybean types under dryland cropping system based on visual injury rating and grain yield. The 1/10th of the label rate reduced soybean yields by an average of 2500 kg ha-1 in Conventional soybean, 2600 kg ha-1 in Glufosinate-tolerant soybean, and 2130 kg ha-1 in Glyphosate-tolerant soybean. In general, off-target movement of Clarity must be prevented as these results suggested that non-dicamba tolerant soybeans were very sensitive to low rates of Clarity.

GROWTH AND DEVELOPMENT OF DRYLAND GLYPHOSATE-TOLERANT, GLUFOSINATE-TOLERANT, AND CONVENTIONAL SOYBEANS AS

INFLUENCED BY MICRO-RATES OF CLARITY. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (107)

There is an increasing number of reports of soybeans damage caused by off-target movement of dicamba based products. A study was conducted to evaluate the influence of micro-rates of Clarity (dicamba) to growth and development of three soybean types (Conventional, Glufosinate-tolerant, and Glyphosate-tolerant soybeans) at three different growth stages of application (V2, V7/R1, and R2) in a dryland cropping system. The study was laid out in a split-split plot arrangement with application time as main plot, soybean types as sub-plot, and Clarity rates (0; 1/10; 1/50; 1/100; 1/500; 1/1000 of the label rate (560 g ae ha-1)) as sub-sub-plot with four replicates. Increase in Clarity dose significantly reduced height and delayed physiological maturity of all soybean types. Clarity dose of 2.89-5.86 g ae ha-1 caused 50% reduction (10-27 cm) in Conventional soybean height; 4.01-8.71 g ae ha-1 dose in Glufosinate-tolerant soybean; and 3.42-6.51 g ae ha-1 dose in Glyphosate-tolerant soybean across three application times. Early season exposure (V2 application timing) of Clarity at 1/10, 1/50, and 1/100 of the label rate did not only reduced plant height but also terminated apical meristem growth which stimulated branching. Clarity dose of 1.38-5.67 g ae ha-1 delayed physiological maturity by 50% (5 to 15 d) in Conventional soybean; 1.94-6.87 g ae ha-1 dose in Glufosinate-tolerant soybean; 1.42-2.34 g ae ha-1 dose in Glyphosate-tolerant soybean, depending on the crop growth stage of Clarity application. Overall, the V7/R1 stage was most sensitive to Clarity compared to V2 and R2 growth stages. The results suggested that off-target movement of Clarity should be prevented to avoid impaired growth and development in all dicamba sensitive soybeans.

GROWTH AND DEVELOPMENT OF IRRIGATED GLYPHOSATE-TOLERANT SOYBEANS AS INFLUENCED BY MICRO-RATES OF ENGENIA. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (108)

Widespread use of dicamba-based herbicide such as Engenia in Dicamba-Tolerant (DT) Soybeans have resulted in un-intended drifts due to windy and common temperature inversions in Nebraska. The objective of this study was to evaluate the sensitivity of growth and development of Roundup-Ready (Glyphosate-tolerant) soybean to micro-rates of Engenia at different growth stages in an irrigated system. A field study was conducted in 2017 at Concord, NE, as a split-plot design with six micro rates of Engenia (0; 1/10; 1/50; 1/100; 1/500; 1/1000 of the label rate (560 g ae ha-1)), three application times (2nd trifoliate (V2), 7th trifoliate/beginning of flowering (V7/R1), and full flowering (R2) growth stages) and four replications. Increase in Engenia dose significantly reduced soybean height and delayed physiological maturity. Engenia dose of 4.41-11.16 g ae ha-1 caused reduction of 12-30 cm in plant height. Reduction in plant height ultimately delayed soybean canopy closure, which can reduce crop competiveness against weeds. Engenia dose of 1.22-3.16 g ae ha-1 delayed maturity by 10-15 d. Overall, the V7/R1 stage was most sensitive to Engenia compared to V2 and R2 stages. For example, a dose of 4.41 g ae ha-1 caused a 50% reduction in plant height compared to 5.92 and 11.16 g ae ha-1 required for V2 and R2 respectively. Engenia also delayed flowering time (d) and reduced number of flowering nodes at 28 DAT for the V2 application time. Increased Engenia dose applied at V7/R1 and R2 timings resulted in increased flower abortion (observations at 14 and 7 DAT respectively). These results suggest the need to ensure proper Engenia application procedures and sprayer cleaning to avoid drift onto Roundup-Ready soybean.

YIELD OF IRRIGATED GLYPHOSATE-TOLERANT SOYBEANS AS INFLUENCED BY MICRO-RATES OF ENGENIA. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (109)

During 2017 field season, there were increased cases of dicamba drift at many soybean fields across Nebraska. Thus, there is a need to understand how micro-rates of dicamba based products (eg. Engenia) could influence the yield of non-dicamba soybeans. In 2017, a field study was conducted at Concord, NE, to evaluate the yield response of Roundup Ready (Glyphosate-tolerant) soybean to micro-rates of Engenia (0, 1/10, 1/50, 1/100, 1/500, 1/1000 of the label rate (560 g ae ha-1)) applied at three different times (V2, V7/R1, and R2 growth stages) in an irrigated system. Increase in Engenia dose significantly increased soybean injury and reduced yield for all application times. Engenia dose of 0.21-1.22 g ae ha-1 caused 50% visual injury at 21 DAT in the glyphosate-tolerant (GT) soybean depending on the application time. The injury levels and symptoms depended on the application time (growth stage). For example, there was cupping of leaves at V2 and V7/R1 timings; twisted stem in V7/R1 and R2 timings; abortion of flowers in V7/R1 timing; swollen nodes and curly pods in R2 timing. Engenia dose of 10.55 to 12.82 g ae ha-1 reduced GT soybean yield by 50% (425 to 2225 kg ha-1). The GT soybean yield appeared to be most affected by Engenia applied at V7/R1 stage, compared to V2 and R2 stages. A 1/10th label rate of Engenia applied at V7/R1 and R2 stages, resulted in plants with less pods and reduced number of seeds per pod than those of V2 stage. In general, Roundup-Ready soybean was sensitive to micro rates of Engenia, suggesting the need to ensure proper herbicide application procedures and sprayer cleaning to avoid Engenia drift onto non-dicamba tolerant soybean.

GROWTH AND DEVELOPMENT OF DRYLAND GLYPHOSATE-TOLERANT, GLUFOSINATE-TOLERANT, AND CONVENTIONAL SOYBEANS AS INFLUENCED BY MICRO-RATES OF ENGENIA. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (110)

In 2017, there were more than 50 reported cases of dicamba drift on sensitive crops including soybeans in Nebraska alone. The degree of soybean injury or damage caused by dicamba drift varied, and this majorly depended on type of crop and growth stage at the time of drift occurrence. A field study was conducted in 2017 at Concord, NE, arranged in a split-split-plot design with three soybean types (Conventional, Glufosinate-tolerant, and Glyphosate-tolerant); six Engenia (dicamba) rates (0, 1/10, 1/50, 1/100, 1/500, 1/1000 of the label rate (560 g ae ha-1)); three application times (2nd trifoliate (V2), 7th trifoliate/beginning of flowering (V7/R1), and full flowering (R2) growth stages); and four replications. Increase in Engenia dose significantly reduced height and delayed physiological maturity of all soybean types in the dryland system. Engenia dose of 2.68-4.79 g ae ha-1 caused 50% reduction (8-31 cm) in Conventional soybean height; 5.31-8.22 g ae ha-1 dose in Glufosinate-tolerant soybean; and 5.11-8.86 g ae ha-1 dose in Glyphosate-tolerant soybean across three application times. The reduced plant height also resulted in delayed canopy closure for V2 timing, and no canopy closure for V7/R1 timing even with the lowest Engenia rate (1/1000 of label rate) in dryland system. Engenia dose of 1.80-5.03 g ae ha-1 delayed physiological maturity by 50% (6 to 12 d) in Conventional soybean; 5.89-8.67 g ae ha-1 dose in Glufosinate-tolerant soybean; 1.16-2.26 g ae ha-1 dose in Glyphosate-tolerant soybean, depending on the crop growth stage of Engenia application. The practical implication is that a delayed maturity would delay harvest and subject the soybeans to frost damage. Exposure of sensitive-soybeans to Engenia at V7/R1 stage consistently had the lowest ED50 values for Glufosinate- and Glyphosate-tolerant soybeans, suggesting V7/R1 was the most sensitive stage. These results suggested the need to ensure proper herbicide application procedures and sprayer cleaning to avoid Engenia drift onto sensitive soybeans.

YIELD OF DRYLAND GLYPHOSATE-TOLERANT, GLUFOSINATE-TOLERANT, AND CONVENTIONAL SOYBEANS AS INFLUENCED BY MICRO-RATES OF ENGENIA. Stevan Z. Knezevic*, O. Adewale Osipitan; University of Nebraska-Lincoln, Concord, NE (111)

Dicamba drifts on sensitive soybeans are of great concern to farmers, which have led to litigations in some cases. Negative impact of dicamba on soybean may vary with dicamba rates, soybean type, and soybean growth stage at the time of drift occurrence. Therefore, a study was conducted to establish a baseline data on the injury and yield sensitivity of soybeans such as Conventional, Liberty-link (Glufosinate-tolerant), and Roundup Ready (Glyphosate-tolerant) soybeans to micro-rates of Engenia (dicamba) applied at three different growth stages in a dryland cropping system. Results suggested that increase in Engenia dose significantly increased soybean injury and reduced yield of all soybean types across all three application times. Injury symptoms depend on the time and rate of Engenia application. Engenia dose of 5.31-14.43 g ae ha-1 reduced yield by 50% (1005 to 1990 kg ha-1) in Conventional soybean; 7.79-18.83 g ae ha-1 in Glufosinate-tolerant soybean; and 5.20-15.5 g ae ha-1 in Glyphosate-tolerant soybean depending on the crop growth stage of Engenia application Overall, V7/R1 was most sensitive growth stage to Engenia for all soybean types For example, in Glyphosate-tolerant soybean, 5.20 g ae ha-1 of Engenia at V7/R1 reduced yield by 50% (2015 kg ha-1), while 7.72 and 15.5 g ae ha-1 were required in V2 and R2 respectively to cause 50% yield reduction. These results suggest the need to ensure proper herbicide application procedures and sprayer cleaning to avoid un-intended Engenia spray that could cause yield reduction in non Dicamba-tolerant soybeans.

GROWTH AND DEVELOPMENT OF IRRIGATED GLYPHOSATE-TOLERANT SOYBEANS AS INFLUENCED BY MICRO-RATES OF XTENDIMAX. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (112)

Commercialization of dicamba-tolerant soybean has led to increased application of dicamba-based products (e.g, XtendiMax) for weed control in many fields in Nebraska (and elsewhere). Environmental conditions and application errors have increased cases of off-target movement of dicamba to sensitive crops including soybeans. Field study was conducted in 2017 at Concord, NE, to evaluate influence of XtendiMax micro-rates on growth and development of irrigated glyphosate-tolerant (Roundup-Ready) soybean. Study was laid-out as a split-plot design with six XtendiMax rates, three application times and four replications. XtendiMax micro-rates were: 0; 1/10; 1/50; 1/100; 1/500; 1/1000 of the label rate (560 g ae ha-1). The 3 application times were 2nd trifoliate (V2), 7th trifoliate/beginning of flowering (V7/R1), and full flowering (R2) growth stages. Results showed that increase in XtendiMax dose significantly reduced soybean height, delayed canopy cover, delayed d to flowering, increased abortion of flowers and delayed physiological maturity. XtendiMax dose of 7.27-9.31 g ae ha-1 caused reduction of 11 to 22 cm in plant height. XtendiMax dose of 0.69-3.96 g ae ha-1 delayed maturity by 11-15 d. Overall, the V7/R1 stage was most sensitive to XtendiMax compared to V2 and R2 stages. Early season exposure (V2 application timing) of XtendiMax at 1/10, 1/50, and 1/100 of the label rate caused termination of apical meristem growth and stimulated branching. These results suggest the need to ensure proper herbicide application procedures and sprayer cleaning to avoid XtendiMax drift onto Roundup-Ready soybean.

YIELD OF IRRIGATED GLYPHOSATE-TOLERANT SOYBEANS AS INFLUENCED BY MICRO-RATES OF XTENDIMAX. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (113)

Off-target movement of dicamba is a growing concern for soybean growers in Nebraska and other states. Yield response of Roundup-Ready (Glyphosate-tolerant) soybean to micro-rates of dicamba (XtendiMax) in an irrigated system was evaluated in 2017 at Concord. Field study was arranged in a split-plot design with six XtendiMax rates (0, 1/10, 1/50, 1/100, 1/500, 1/1000 of the label rate (560 g ae ha-1)) applied at three times (2nd trifoliate (V2), 7th trifoliate/beginning of flowering (V7/R1), and full flowering (R2) growth stages). Plots were 10 m long and 3 m wide, and planted with four rows of glyphosate-tolerant (GT) soybean in 3 replicates. Increase in XtendiMax dose significantly increased soybean injury and reduced yield for all application times. XtendiMax dose of 0.30-1.38 g ae ha-1 caused 50% soybean injury at 21 DAT depending on the application time. The sizes of pods decreased with increased XtendiMax rate for V7/R1 and R2 timing. XtendiMax dose of 11.92 to 20.99 g ae ha-1 reduced yield by 50% (275 to 1900 kg ha-1) depending on the crop growth stage of XtendiMax application. For example, 11.92 g ae ha-1 of XtendiMax dose caused a 50% reduction in soybean yield (1900 kg ha-1) at V7/R1 stage, compared to 20.99 and 15.51 g ae ha-1 dose required at V2 and V7/R1 stage respectively. Overall, the V7/R1 growth stage was most sensitive to XtendiMax compared to V2 and R2 growth stages. Off-target movement of XtendiMax must be avoided to prevent yield reduction, as Roundup-Ready soybean is sensitive to micro rates of XtendiMax.

GROWTH AND DEVELOPMENT OF DRYLAND GLYPHOSATE-TOLERANT, GLUFOSINATE-TOLERANT, AND CONVENTIONAL SOYBEANS AS INFLUENCED BY MICRO-RATES OF XTENDIMAX. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (114)

Weed control programs with dicamba has been encouraging particularly in dicamba-tolerant (DT) crops. However, the off-target movement of dicamba (e.g XtendiMax) could cause various degree of impaired growth and development to non-DT soybeans. A field study was conducted in 2017 at Concord, Nebraska, to evaluate the influence of micro-rates of XtendiMax on growth and development of three soybean types (Conventional, Glufosinate-tolerant, and Glyphosate-tolerant) applied at three different application times (V2, V7/R1 and R2 growth stages of soybean). Data on plant height, number of branches, d to flowering, number of flowering nodes, d to canopy closure, and d to physiological maturity were collected. XtendiMax dose of 1.86-3.89 g ae ha-1 caused 50% reduction (10-29 cm) in height of conventional soybean; the 4.88-6.27 g ae ha-1 dose in Glufosinate-tolerant soybean; and 3.52-8.39 g ae ha-1 dose in Glyphosate-tolerant soybean across three application times. XtendiMax dose of 1.56-5.29 g ae ha-1 delayed physiological maturity by 6 to 12 d in Conventional soybean; 1.81-5.13 g ae ha-1 dose in Glufosinate-tolerant soybean; 1.06-2.81 g ae ha-1 dose in Glyphosate-tolerant soybean, depending on the crop growth stage of XtendiMax application. XtendiMax also delayed flowering time (d) and reduced number of flowering nodes at 28 DAT for the V2 application time. Increased dose of XtendiMax applied at V7/R1 and R2 timings resulted in higher flower abortion (at 14 and 7 DAT respectively). Based on plant height and delays in d to physiological maturity, V7/R1 stage was the most sensitive to XtendiMax compared to V2 and R2 stages. In general, increase in XtendiMax dose significantly reduced plant height, delayed physiological maturity of all soybean types, delayed flowering time, and reduced number of flowers. These results implied that off-target-application of XtendiMax should be avoided at all costs to prevent negative impact on growth and development of non-dicamba soybeans.

YIELD OF DRYLAND GLYPHOSATE-TOLERANT, GLUFOSINATE-TOLERANT, AND CONVENTIONAL SOYBEANS AS INFLUENCED BY MICRO-RATES OF XTENDIMAX. Stevan Z. Knezevic, O. Adewale Osipitan*; University of Nebraska-Lincoln, Concord, NE (115)

Adoption of dicamba-tolerant (DT) soybean by farmers has increased the use of dicamba based products (e.g. XtendiMax) for weed control in many soybean fields. However, there were many cases of off-target movement of dicamba based products to non-DT soybeans. A field study was conducted in 2017 at Concord, NE, to evaluate sensitivity of yields in three soybean types (Conventional, Liberty-link (Glufosinate-tolerant), and Round-up Ready (Glyphosate-tolerant)) to micro-rates of XtendiMax at three different growth stages of application in dryland system. XtendiMax dose of 5.09-16.4 g ae ha-1 reduced yield by 50% (1125 to 1935 kg ha-1) in Conventional soybean; 6.95-19.3 g ae ha-1 in Glufosinate-tolerant soybean; and 6.34-20.0 g ae ha-1 in Glyphosate-tolerant soybean depending on the crop growth stage of application. Soybean yields were most sensitive to XtendiMax at V7/R1 growth stage compared to V2 and R2 stages in Glufosinate- and Glyphosate-tolerant soybeans. High sensitivity of soybean yield at V7/R1 may be attributed to high abortion of flowers recorded after application of micro-rates of XtendiMax. In all soybean types, R2 appeared relatively less sensitive compared to V2 and V7/R1 stages based on visual injury rating and yield reduction in the dryland system. However, at the highest evaluated rate (1/10th of XtendiMax label rate), soybean yields were reduced by an average of 2700kg ha-1 in R2 than 2200 kg ha-1 yield reduction in V2, across all soybean types. In general, these results showed that non-DT soybeans were sensitive to micro-rates of XtendiMax, hence, efforts should be made to avoid drift of XtendiMax onto these soybeans.

LEWIS AND CLARK EXPEDITION: SOLDIERS AS SCIENTISTS. Erin Hilligoss-Volkmann*1, Paul Rosewitz2; 1National Park Service, St. Louis, MO, 2National Archives and Records Administration, St. Louis, MO (116)

MANAGING HERBICIDE RESISTANCE: LISTENING TO THE PERSPECTIVES OF THE PRACTITIONERS. Jill Schroeder*1, David R. Shaw2, Michael Barrett3, Harold Coble4, Amy Asmus5, Raymond Jussaume6, David Ervin7; 1USDA Office of Pest Management Policy, Washington, DC, 2Mississippi State University, Mississippi State, MS, 3University of Kentucky, Lexington, KY, 4North Carolina State University Professor Emeritus, Raleigh, NC, 5Asmus Farm Supply, Inc., Rake, IA, 6Michigan State University, East Lansing, MI, 7Portland State University, Portland, OR (117)

NCWSS PRESIDENTIAL ADDRESS. Gregory K. Dahl*; Winfield United, River Falls, WI (119)

Welcome to the 72nd annual meeting of the North Central Weed Science Society (NCWSS). Thank you for the opportunity to serve as your President in 2017. This year many challenges were presented to us and there is plenty to do. We have a great meeting planned. Thanks to Christy Sprague, President-Elect and Program Chair for putting together a great program. Thanks to Greg Elmore Local Arrangements Committee Chair and the Local Arrangements Committee for planning and hosting a great meeting. Thanks to the Hyatt Regency St. Louis, at the Arch for having us for our meeting. I am very pleased that Tara Steinke has done a great job as our

Executive Secretary this year. Please help me thank her for her efforts. Thanks again to John Hinz, Warren Pierson and the Weed Contest Committee, Coaches and participants for the great NCWSS Weed Contest held this summer. It was tremendous. Thanks to the NCWSS Board of Directors, Past Presidents, Committees and everyone else that helped. The NCWSS succeeds because of our volunteer's efforts. I have been amazed at the way so many of you volunteer and work to make the NCWSS a great organization. We have accomplished a lot this year and will be in good shape as we move forward. I encourage you to volunteer and make NCWSS even better. If you have suggestions of how the NCWSS could improve please contact me or one of the NCWSS Board members. Thanks again.

GENOMIC AND MOLECULAR STUDIES OF KEY WEEDS. Philip Westra*; Colorado State University, Fort Collins, CO (122)

New tools and techniques are being used to better understand the world of biology including plants such as weeds. Molecular marker systems are being used to accelerate the selection and development of new crop varieties for growers, and CRISPER-CAS9 will increasingly be used to make specific DNA changes in crops. Molecular diagnostic tests can determine if selected weed populations are already resistant to a given herbicide, whether such resistance be due to an altered target site or to non-target site metabolism. In some examples, advanced sequencing and bioinformatics can identify specific metabolism genes that confer herbicide resistance. To date, only three weed genomes have been published and are available as tools for others to use in their molecular research programs. Transcriptome data is available for quite a few other weed species. Full genome sequence data is being developed for some key herbicide resistant weeds such as Palmer amaranth and kochia. Such sequence data can be used to compare the genetic makeup of key weeds compared to closely related crop relatives for which there is a greater supply of genomic sequence data. New graduate students entering the profession of weed science will increasingly be expected to have a working knowledge of these new tools and the technology associated with them. At Colorado State University, this transition is already well under way.

INVESTIGATION OF MECHANISMS AND GENETIC BASIS OF DICAMBA RESISTANCE IN KOCHIA FROM KANSAS AND COLORADO. Junjun Ou*1, Dean Pettinga2, Phillip Stahlman3, Phil Westra4, Todd A. Gaines2, Mithila Jugulam5; 1Kansas State Univ., Dep of Agronomy, Manhattan, KS, 2Colorado State University, Fort Collins, CO, 3Kansas State University, Hays, KS, 4Colorado State Univ, Ft Collins, CO, 5Kansas State University, Manhattan, KS (123)

Kochia is a problem weed throughout the US Great Plains. Evolution of resistance to multiple herbicides in kochia is challenging the sustainability of herbicide-resistant crop technologies. The evolution of dicamba resistance in glyphosate-resistant kochia in KS, CO, and other High Plains states has become a serious threat to manage this weed in dicamba-resistant crop technology embraced fields. The objective of this research was to uncover the mechanism(s) of dicamba resistance in kochia populations from KS and CO using physiological and genetic approaches. Absorption, translocation, and metabolism of [14C] dicamba were determined in dicamba-resistant (DR) and dicamba-susceptible (DS) kochia populations from KS and CO. Furthermore, genetic analyses were performed by generating F1 and F2 progenies using DR kochia from KS and CO as parents. The results of this study demonstrate that different mechanisms confer dicamba resistance in kochia from KS and CO. While the dicamba resistance in kochia from CO was bestowed by reduced translocation of dicamba, no apparent difference in dicamba absorption, translocation, or metabolism was found between DR or DS kochia from KS. Additionally, genetic analyses of the F2 progeny found that two different genes control dicamba resistance in kochia from KS and CO. Results from both physiological and genetic approaches were supported by phosphor image analyses. Overall, the outcome of this research suggests that different populations of the same weed species can evolve resistance to the same herbicide by different mechanisms.

IDENTIFICATION OF THE GENETIC BASIS FOR DICAMBA RESISTANCE IN KOCHIA. Sherry LeClere*1, R. Douglas Sammons1, Phil Westra2; 1Monsanto, Chesterfield, MO, 2Colorado State Univ, Ft Collins, CO (124)

GENETICS OF RESISTANCE TO 2,4-D IN TWO WATERHEMP POPULATIONS FROM THE MIDWESTERN UNITED STATES. Sebastian Sabate*1, Mark Bernards2, Greg R Kruger3, Aaron Hager1, Patrick Tranel1; 1University of Illinois, Urbana, IL, 2Western Illinois University, Macomb, IL, 3University of Nebraska, North Platte, NE (125)

Resistance to six different modes of action has been described in waterhemp (Amaranthus tuberculatus) so far, the last one corresponding to auxin herbicides. Resistance to 2,4-D was described first in a grass seed production area in Nebraska (NE) in 2009, and later in a crop field in Illinois (IL). To address the genetic and inheritance of this trait, we studied the levels of resistance and inheritance patterns for both 2,4-D resistant (R) populations in parallel. F1 generations were obtained from reciprocal crosses between the resistant and a sensitive population, from which different pseudo-F2 generations and backcross to sensitive (BCS) populations were derived. Dose-response studies for the parental and F1 populations were carried out. Phenotypic ratios of F2 and BCS were contrasted to those expected for single-gene inheritance using Chi-square analysis. Based on dry weight data, 2,4-D resistant/sensitive ratios of R parental populations were 27 and 31, while F1 populations averaged 11 and 15, both for NE and IL, respectively. For both populations, resistance was nuclear inherited and at least partially dominant. The NE F1 populations showed segregation patterns indicating they may have been derived from heterozygous plants. The segregation ratios of plants sprayed with a discriminating rate 560 g a.e. ha-1 2,4-D indicate the presence of a main single gene conferring resistance in the NE population. In contrast, the IL population did not yield F2 segregation ratios compatible with single-gene inheritance, indicating the possible influence of more than one gene in the resistant trait. These results suggest the selection of different mechanisms of evolved resistance to 2,4-D in different waterhemp populations, which is concerning given the increasing use of auxin-tolerant crop technologies.

INVESTIGATING EFFICACY OF SELECTED VERY LONG CHAIN FATTY ACID-INHIBITING HERBICIDES ON TALL WATERHEMP POPULATIONS WITH EVOLVED MULTIPLE HERBICIDE RESISTANCES. Eric Jones*; Iowa State University, Ames, IA (126)

Very long chain fatty acid (VLCFA)-inhibiting herbicides have been applied to maize and soybean fields in Iowa since the 1960s. There are no confirmed weed populations in Iowa with evolved resistance to the VLCFA inhibiting herbicides. Recently, VLFCA-inhibiting herbicides have been applied more extensively to control multiple herbicide-resistant Amaranthus tuberculatus (waterhemp) populations. Waterhemp has evolved resistance to six herbicide sites-of-action (herbicide group [HG] 2, 4, 5, 9, 14, and 27). The hypothesis is with increasing herbicide resistances within a waterhemp population, the VLCFA-inhibiting herbicides will provide less than acceptable control. The objective of this study was to determine if increasing levels of multiple-herbicide resistances in waterhemp will decrease VLCFA-inhibiting herbicide control. Dose-response assays were conducted in the field and germination chamber to determine the efficacy of three VLCFA-inhibiting herbicides, acetochlor, s-metolachlor, and flufenacet, on selected populations of multiple herbicide-resistant waterhemp. Multiple herbicide-resistant waterhemp populations (HG 2, 5, 9, and 27 and HG 2, 14, and 27) from Grundy and Story County fields, respectively did not respond differently to all herbicides tested. In the germination chamber, three-way (HG 2, 5, and 27), four-way (HG 2, 5, 9, and 27), and five-way (HG 2, 5, 9, 14, and 27) herbicide-resistant waterhemp populations responded to the herbicide treatments similarly to the herbicide-susceptible population. There was a difference in control between the herbicides. Acetochlor achieved the highest control followed by s-metolachlor then flufenacet.

MOLECULAR SURVEY OF GLYPHOSATE AND PPO-INHIBITOR RESISTANCE MECHANISMS IN OHIO TALL WATERHEMP POPULATIONS. Brent Murphy*1, Alvaro S. Larran2, Bruce Ackley3, Mark Loux4, Patrick Tranel1; 1University of Illinois, Urbana, IL, 2Universidad Nacional de Rosario, Zavalla, Argentina, 3The Ohio State University, Columbus, OH, 4Ohio State University, Columbus, OH (127)

The spread and prevalence of herbicide resistance within driver species such as Amaranthus tuberculatus impact management options available to producers. Here we outline the spatial distribution of known mechanisms of resistance to key herbicides glyphosate, PPO inhibitors, and atrazine within A. tuberculatus in the state of Ohio. In regards to glyphosate resistance, EPSPS gene-amplification was observed in nearly all tested populations, whereas the P106S EPSPS substitution occurred infrequently. Several instances of a glyphosate-resistant plant possessing both gene amplification and the P106S mutation were observed. Resistance to PPO inhibitors mediated by the PPO G210 deletion was observed in high frequency in two populations in Mercer County and Hardin County. No instances of R98 PPO mutations were observed within PPO-inhibitor-resistant plants. Resistance to atrazine was observed at low frequencies in most tested populations, however high frequencies of atrazine resistance were observed in a single population in Mahoning County and Mercer County. No instances of the G264S D1 substitution, which confers atrazine resistance, were observed in the tested populations. Continued surveillance of target weedy species is necessary to maintain accurate information for producers, allowing optimal management decisions to be made.

A MULTI-STATE SURVEY TO DETERMINE THE POTENTIAL FOR RESISTANCE TO PPO-INHIBITING HERBICIDES IN TALL WATERHEMP BEYOND THE G210 TARGET SITE MUTATION. Brent C. Mansfield*1, Haozhen Nie1, Julie M Young2, Kevin W Bradley3, Bryan G. Young1; 1Purdue University, West Lafayette, IN, 2, Brookston, IN, 3University of Missouri, Columbia, MO (128)

Protoporphyrinogen oxidase (PPO)-inhibiting herbicides are frequently used throughout the Midwest in soybean production to manage pigweed species, such as tall waterhemp (Amaranthus tuberculatus). Tall waterhemp was the first weed to evolve resistance to PPO-inhibiting herbicides and has been confirmed in seven Midwest states to date. The only known mechanism of resistance is a target site mutation resulting in deletion of a glycine at position 210 on the PPX2L gene. Enhanced molecular techniques using TaqMan assays for real-time polymerase chain reaction (qPCR) have allowed scientists to quickly and accurately determine the presence or absence of herbicide target site mutations. Tall waterhemp tissue samples submitted to university labs suspected to be resistant to PPO-inhibiting herbicides do not always receive positive confirmation of the ΔG210 deletion. To investigate these anomalies, a multi-state survey was conducted to determine the potential for alternative resistance mechanisms in tall waterhemp beyond the ΔG210 target site mutation. Preliminary greenhouse experiments in fall 2016 were conducted to characterize the general response of 148 tall waterhemp populations from Illinois, Indiana, Iowa, Missouri, and Minnesota to three discriminating rates of fomesafen. Herbicide rates included 13, 52, and 416 g ai ha-1 with the addition of 1% v v-1 crop oil concentrate (COC) with visual estimates of control assessed at 3, 7, and 14 d after treatment (DAT). Tissue samples of surviving plants were collected 14 DAT. DNA was extracted and subjected to qPCR for determination of the presence or absence of the ΔG210 deletion. Results from the initial discriminating dose screen revealed that 125 of 148 tall waterhemp populations contained plants with the ΔG210 deletion. Following the preliminary greenhouse experiments, three methods were used to identify tall waterhemp populations that potentially exhibited an alternative resistance mechanism to PPO-inhibiting herbicides other than the ΔG210 deletion. These methods identified populations that exhibited potential low-, mid-, or high-level resistance mechanisms. Low-level resistance was defined as populations with a low frequency of ΔG210 and plant responses to fomesafen between known susceptible populations without ΔG210 and known-resistant populations with a high frequency of ΔG210. Mid-level resistance was defined as populations with a low frequency of ΔG210 and plant responses to fomesafen different from known-susceptible populations, but similar to known-resistant populations. High-level resistance was defined as plant responses with less sensitivity to fomesafen than known-susceptible and known-resistant populations. Populations selected from the preliminary greenhouse experiments were subjected to a full dose response experiment to calculate relative GR50 values and the ratio of GR50-Resistant to GR50-Susceptible biotypes (R/S). Using the three methods, ten populations fit the criteria for low-level resistance, one population fit the criteria for mid-level resistance, and nineteen populations fit the criteria for high-level resistance.

PRESENCE OF AN ALTERNATIVE MECHANISM OF RESISTANCE TO PPO-INHIBITING HERBICIDES IN TALL WATERHEMP POPULATIONS FROM INDIANA, ILLINOIS, IOWA, MISSOURI, AND MINNESOTA. Nicholas R. Steppig*1, Brent C. Mansfield1, Haozhen Nie1, Julie M. Young2, Bryan G. Young1; 1Purdue University, West Lafayette, IN, 2Purdue University, WEST LAFAYETTE, IN (129)

Protoporphyrinogen oxidase (PPO)-inhibiting herbicides (group #14 herbicides) are widely utilized across the Midwestern US for management of tall waterhemp (Amaranthus tuberculatus), specifically glyphosate-resistant biotypes. Group #14 herbicides have been in use for nearly 50 years; however, group #14 herbicide-resistance in tall waterhemp was not documented until 2001. To date, resistance in tall waterhemp to group #14 herbicides has been attributed to a glycine deletion at the 210th position (G210) of the PPX2L gene. Tall waterhemp populations from 148 fields in five Midwestern states with a history of group #14 herbicide use were surveyed in fall 2016, subjected to a whole-plant greenhouse experiment using fomesafen at discriminating doses, and surviving plants assayed for the presence of the G210 mutation. Results from the G210 assay showed that the mutation was absent in a number of plants that survived fomesafen applications, indicating the potential that resistance is being conferred by an alternative mechanism. In early 2017, two new mutations at the R98 site of the PPX2L gene were shown to be associated with reduced sensitivity to PPO-inhibiting herbicides in Palmer amaranth (Amaranthus palmeri). These mutations conferred resistance by changing the wild type codon from an arginine to either a methionine or glycine, and are referred to as R98M and R98G, respectively. It was hypothesized that a similar mutation may help explain the instances of surviving tall waterhemp plants that tested negative for presence of the G210 mutation following fomesafen applications in dose response studies. Based on this criteria, a population of interest from Gibson County, Indiana (Gib5) was chosen, and the PPX2L region of its genome sequenced via traditional sequencing methods. Sequencing results confirmed the presence of the R98G mutation, as well as the G210 mutation, in the Gib5 population. From this population, crosses were performed under greenhouse conditions to create lines homozygous for both the R98G and G210 mutations, plus a line with one copy of each mutation. A full dose response greenhouse experiment was conducted to compare levels of resistance in this population conferred via R98G in relation to the G210 mutation, as well as in the heterozygous line. Additionally, in order to test for the presence and prevalence of the R98 mutation in tall waterhemp populations surveyed, DNA from all surviving plants from the 2016 greenhouse dose response tests were pooled to form a composite sample for each population. DNA from these composite samples was subjected to WideSeq next-generation sequencing in order to investigate the region around the R98 site. The presence of a mutation at the R98 position has been confirmed in at least one population from the multistate survey. Information provided via WideSeq analysis will help explain the distribution of this mutation in Midwestern waterhemp populations and provide valuable insight into mechanisms of resistance to group #14 herbicides aside from the G210 mutation.

MOLECULAR AND PHYSIOLOGICAL CHARACTERIZATION OF MULTIPLE HERBICIDE RESISTANCE IN A MISSOURI WATERHEMP POPULATION. Lovreet S. Shergill*1, Mandy Bish1, Mithila Jugulam2, Kevin Bradley1; 1University of Missouri, Columbia, MO, 2Kansas State University, Manhattan, KS (130)

In 2014, a grower from north central Missouri reported failure to control a waterhemp population with numerous herbicides, including 2,4-D. Subsequent field and greenhouse experiments confirmed six-way resistance to 2,4-D (synthetic auxins), glyphosate (5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)), fomesafen (protoporphyrinogen oxidase (PPO)), chlorimuron (acetolactate synthase (ALS)), atrazine (photosystem II (PSII)), and mesotrione (4-hydroxyphenyl-pyruvate-dioxygenase (HPPD)) herbicides in this waterhemp population (MO-Ren). The objective of this study was to investigate the mechanisms of multiple herbicide resistance in this waterhemp population. Genomic DNA sequencing confirmed the presence of mutations associated with ALS- and PPO-inhibitor resistance: the point mutation resulting in the Trp-574-Leu amino acid substitution in the ALS enzyme and the codon deletion corresponding to the ΔG210 in the PPO2 enzyme. Point mutations in the psbA and EPSPS genes associated with resistance to PSII and EPSPS inhibiting herbicides, respectively, were not detected. Quantitative polymerase chain reaction (qPCR) indicated that MO-Ren plants contained five-fold more copies of the EPSPS gene than did susceptible plants. A whole plant greenhouse study using malathion (a cytochrome P450 inhibitor) and NBD-Cl (a GST inhibitor) was conducted to understand the mechanism of resistance to 2,4-D, atrazine, mesotrione and chlorimuron. Malathion in combination with 2,4-D, mesotrione and chlorimuron POST enhanced the activity of these herbicides indicating that cytochrome P450's were involved in conferring herbicide resistance. NBD-Cl was used in combination with atrazine and did not improve biomass reduction, indicating that either GST's unaffected by NBD-CI or other mechanisms are responsible for the atrazine resistance. The physiological basis of decreased 2,4-D efficacy was studied through absorption and translocation assays of [14C] 2,4-D. Results suggest that these mechanisms were not involved in the 2,4-D resistance. However, 2,4-D was metabolized seven to nine-fold faster in MO-Ren population than in the susceptible population.

QUANTIFYING RESISTANCE TO ISOXAFLUTOLE AND MESOTRIONE AND THEIR INTERACTION WITH METRIBUZIN POST IN TALL WATERHEMP. Sarah O'Brien*1, Adam Davis2, Dean E Riechers3; 1University of Illinois at Urbana-Champaign, Urban, IL, 2N-319 Turner Hall, Urbana, IL, 3Univ of Illinois Crop Science, Urbana, IL (131)

Resistance to mesotrione and other 4-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibiting herbicides has recently occurred in waterhemp (Amaranthus tuberculatus). Experiments were conducted to quantify the level of resistance to mesotrione or isoxaflutole applied postemergence (POST) in the NEB (for Nebraska HPPD-resistant) and SIR (for Stanford, Illinois HPPD-resistant) waterhemp populations, which differ in their histories of HPPD-inhibitor use in the field. Foliar responses of NEB and SIR were compared to ACR (HPPD-sensitive but atrazine-resistant) and SEN (for herbicide sensitive) waterhemp populations to generate fold-resistance ratios. A greenhouse dose-response study was conducted with each herbicide at two different POST timings: an EPOST (5 cm tall or 4-5 true leaves) and POST (10 cm tall or 8-9 true leaves). SIR was 24-fold resistant to isoxaflutole and 35-fold resistant to mesotrione EPOST compared to SEN, and NEB was eight-fold resistant to both isoxaflutole and mesotrione EPOST compared to SEN. Furthermore, SIR was 27-fold resistant to isoxaflutole and 21-fold resistant to mesotrione POST compared to SEN, while NEB was five-fold resistant to isoxaflutole and seven-fold resistant to mesotrione POST compared to SEN. These findings did not indicate a consistent pattern in fold-resistance levels to isoxaflutole in taller plants. In contrast, mesotrione applied POST to SIR showed a clear decrease in fold-resistance levels relative to EPOST. To further investigate potential management strategies for NEB and SIR in the field, a POST herbicide interaction study was conducted using combinations of metribuzin and either isoxaflutole or mesotrione. Following dose-response analysis of several sublethal metribuzin rates, 191 g ai ha-1 was chosen for interaction studies since this rate caused an approximate 20% biomass reduction to SIR and NEB plants. This metribuzin rate was combined with either a 0, 0.5, 1, or 2x field-use rate of either isoxaflutole or mesotrione. Results indicated that mesotrione at 52.5 g ai ha-1 combined with 191 g ai ha-1 of metribuzin displayed a synergistic effect on biomass reduction in SIR plants. All other combinations of either mesotrione or isoxaflutole and metribuzin resulted in an additive effect on biomass reduction in both the SIR and the NEB populations. These results give insight into how the joint activity between HPPD- and certain PSII-inhibitors can be used to control metabolism-based, multiple herbicide-resistant waterhemp populations.

OVEREXPRESSION HOTSPOTS IN HERBICIDE-RESISTANT WATERHEMP. Darci Giacomini*, Patrick Tranel; University of Illinois, Urbana, IL (132)

In the last decade, waterhemp (Amaranthus tuberculatus) has evolved resistance to 2,4-D and HPPD inhibitors in multiple states across the midwestern US. Two populations resistant to both chemistries, one from Nebraska (NEB) and one from Illinois (CHR), were studied using an RNA-seq approach to identify the genes responsible for resistance. In this study, cDNA libraries were generated and sequenced for eight replicates of herbicide-resistant (HR) and herbicide-sensitive (HS) plants from the two populations (32 total plants sequenced). Using both a waterhemp transcriptome assembly and a high-quality grain amaranth (A. hypochondriacus) genome as references, differential gene expression analysis was conducted to identify genes that were over- or under-expressed in HR compared to HS. When these differentially expressed genes (DEGs) were mapped back to the grain amaranth genome, physical clustering of the DEGs was apparent along several of the 16 grain amaranth scaffolds. In almost every one of these expression “hotspots”, allele-specific expression was also observed, allowing for the development of allele-specific assays to diagnose resistance problems in fields. These expression hotspots are a potentially useful tool in future RNA-seq studies to narrow down the regions of true regulatory control leading to resistance, and they may also provide insights into the evolution of herbicide resistance in weeds.

DIFFERENTIAL GENE EXPRESSION IN HORSEWEED IN RESPONSE TO HALAUXIFEN-METHYL, DICAMBA, AND 2,4-D. Cara L. McCauley*, Bryan G. Young; Purdue University, West Lafayette, IN (133)

Auxins are a class of small plant hormones that are involved in nearly every aspect of plant growth and development. Synthetic auxin herbicides are classified as such due to their auxin-like chemical structure and plant physiological response following application. Synthetic auxin herbicides including 2,4-D (phenoxy chemical family) and dicamba (benzoic acid chemical family) have been used as components of herbicide-resistance management strategies, including management of glyphosate-resistant horseweed (Conyza canadensis). Halauxifen-methyl is a new arylpicolinate herbicide that represents another auxin chemical class and has shown a high level of efficacy on horseweed and other broadleaf weed species. The complex network of plant hormone interactions that are perturbed by exogenous synthetic auxin herbicide applications provide a unique opportunity to employ transcriptomics to study herbicide response in a target weed species such as horseweed. Greenhouse-grown horseweed rosettes were sprayed with halauxifen-methyl, dicamba, and 2,4-D at 5, 280, and 560 g ae ha-1, respectively. Leaf tissue was collected from treated plants at one and six hr after herbicide treatment (HAT) for analysis and RNA sequencing was conducted using 2X100 base pair reads on the Illumina-Hiseq 2500 platform. The horseweed draft genome was annotated using GeneMark and transcript reads were mapped back to this genome using STAR aligner. Differential gene expression analysis included edgeR, DESeq2, and Cufflinks; transcripts significant in two of the three analyses were included in the results. At one HAT, 48 transcripts, or 5% of the total number of differentially expressed genes, were up-regulated in all three herbicides. Among these were expected auxin-responsive genes such as Aux/IAA, GH3, and SHY2. The enzyme involved in the rate-limiting step of ABA biosynthesis, NCED, was up-regulated in all three herbicides at the early and late time points. There were no down-regulated genes at one HAT for the halauxifen-methyl treatment, but 2,4-D and dicamba treatments down-regulated 256 and 296 genes, respectively, 120 of which were down-regulated by both herbicides. ACC synthase, the enzyme involved in the rate-limiting step of ethylene production were differentially up- and down-regulated at the later time point, but there was no differential expression in any treatment at one HAT. ACC oxidase, the enzyme that converts ACC to ethylene was down-regulated at six HAT in all herbicide treatments. The overall transcriptome profile indicates that approximately 73 and 48% of differentially expressed genes were exclusive to a single herbicide at one and six HAT, respectively. This research presents a first look into how these herbicides elicit different gene expression profiles after foliar application. A fine-tuned pathway analysis and identification of key genes involved in upstream transcriptome regulation is required to further differentiate herbicide action. Future research will include qPCR validation to confirm differential gene expression with an alternative quantification method. Additionally, physiological validation experiments including ABA quantification will be conducted to evaluate the time course of NCED gene expression in response to each auxin herbicide.

DIFFERENTIAL ANTIOXIDANT ENZYME PROFILES IN RAPID RESPONSE GLYPHOSATE-RESISTANT GIANT RAGWEED. Nick T. Harre*1, Haozhen Nie2, Yiwei Jiang2, Bryan G. Young2; 1Purdue University, Nashville, IL, 2Purdue University, West Lafayette, IN (134)

The rapid response (RR) giant ragweed biotype displays a sacrificial form of glyphosate resistance. In less than one hr after treatment (HAT) with glyphosate, H_2O_2 accumulates from an oxidative burst in mature leaves, thus resulting in water-soaked lesions and a rise in chlorophyll fluorescence within six HAT and complete loss of mature leaves by 72 HAT. Juvenile leaves of the RR biotype accumulate a minimal amount of H_2O_2, remain uninjured, and resume normal growth within a wk after treatment. Previous work has documented the oxidative burst in mature leaves effectively limits glyphosate translocation to apical meristems, however, the cause of the differential response between mature and juvenile leaves remains unknown. Reports in Conyza spp. have shown elevated antioxidant enzyme levels in paraquat-resistant biotypes endow tolerance by scavenging reactive oxygen species (ROS) faster than susceptible biotypes. Thus, research was performed to assess the safening capacity of antioxidant enzymes as a putative cause of the differential tissue response following glyphosate treatment between juvenile and mature leaves in RR giant ragweed. Moreover, work was conducted to determine if the RR biotype is inherently more tolerant than the glyphosate-susceptible (GS) biotype to other forms of oxidative stress. Measurements of lipid peroxidation and antioxidant enzyme activity were taken at 0, 2, 4, 8, 16, and 32 HAT with 840 g a ha-1 glyphosate from juvenile and mature leaves of RR and GS biotypes. Lipid peroxidation in RR mature leaves accelerated quickly from 8 to 32 HAT while remaining unchanged in juvenile and mature leaves of the GS biotype. The extent of lipid peroxidation in juvenile leaves of the RR biotype was similar to the GS biotype indicating minimal damage from the RR oxidative burst. Enzymatic antioxidant activities for superoxide dismutase, catalase, and guaiacol peroxidase did not suggest any of these to be involved in protection of RR juvenile leaves from oxidative damage. Rather, several enzymes involved in the ascorbate-glutathione cycle (ascorbate peroxidase, dehydroascorbate reductase, and glutathione reductase) increased in activity from zero to eight HAT in RR juvenile leaves only. After this period, activities of these enzymes declined and approached basal levels. Based on GR50 estimates, sensitivity to the strong oxidant paraquat was similar between RR and GS biotypes. Therefore, the differential tissue response to the glyphosate-induced oxidative burst in RR giant ragweed is at least partially explained by a transient rise in activity of ascorbate-glutathione cycle enzymes in juvenile leaves prior to eight HAT. However, tolerance towards the RR oxidative burst does not appear to extend to other oxidative stressors such as ROS-generating herbicides. This is the first report detailing antioxidant enzyme involvement in a glyphosate-resistant weed.

RELATIONSHIP BETWEEN GLUFOSINATE PHYTOTOXICITY, INHIBITION OF GLUTAMINE SYNTHETASE AND AMMONIA ACCUMULATION. Hudson Takano*1, Phil Westra2, Franck E. Dayan1; 1Colorado State University, Fort Collins, CO, 2Colorado State Univ, Ft Collins, CO (135)

Glufosinate inhibits glutamine synthetase (GS) by competing with glutamate for the same binding site on the enzyme. The irreversible binding of glufosinate on GS stops the amination of glutamate into glutamine, causing a rapid accumulation of ammonia within leaf tissue. Although the inhibition of GS is the main glufosinate mode of action, the reason why plants show rapid injury after glufosinate exposure might be associated with inhibition of photosynthesis. There has been research attempting to clarify whether or not the accumulation of ammonia is linked to inhibition of photosynthesis, but the mechanism of photosynthetic inhibition remains to be fully elucidated. Therefore, the objective of this research is to better understand the relationship between glufosinate phytotoxicity, the inhibition of GS, and ammonia accumulation, which may help to provide opportunities to enhance the herbicidal effect of glufosinate. For all experiments, four weed species with different carbon assimilation pathways were utilized: Sinapsis arvensis (C3), Amaranthus palmeri (C4), Lolium rigidum (C3), and Sorghum halepense (C4). A dose response experiment was conducted in the greenhouse using 0, 9, 28, 93, 280, 560, 1120 and 2240 g ai ha-1 of glufosinate, and evaluating visual phytotoxicity over time. Tissue samples were collected from the same plants at one, two, four and eight hr after treatment (HAT) and analyzed for enzyme activity. The accumulation of ammonia was measured by a leaf disc assay in the presence of increasing glufosinate concentrations for 24 hr under photorespiratory conditions. Experiments were repeated twice. In the greenhouse, A. palmeri was the most sensitive species followed by S. arvensis, S. halepense and L. rigidum. The inhibition of GS and the accumulation of ammonia were also stronger for A. palmeri than S. arvensis, and S. halepense. No accumulation of ammonia was observed for L. rigidum within the range of tested doses and the GS activity was inhibited only with the highest dose of glufosinate. In general, a linear relationship between visual phytotoxicity, inhibition of GS, and accumulation of ammonia was observed. Sensitive weeds such as A. palmeri have more inhibition of GS and accumulate more ammonia than other species. On the other hand, tolerant species like L. rigidum accumulate less ammonia and have their enzyme inhibited only with high doses of glufosinate. Future research will include the investigation of the relationship between GS inhibition and photorespiration and how it affects photosynthesis and glufosinate efficacy.

SPECIALTY ADDITIVES FOR IMPROVED RESIDUAL HERBICIDE EFFICACY. Marc A. McPherson*, Justin Heuser, Ryan Stiltoner; Evonik Corporation, Richmond, VA (136)

Grower emphasis on residual herbicides to control weeds throughout the growing season has increased largely because of weed resistance to glyphosate. Field trials were conducted to evaluate the potential for enhanced efficacy of several residual herbicides by using specialty additives. A diversity of specialty additives were applied after planting soybeans with the herbicides fomesafen, flumioxazin, pyroxasulfone, and s-metolachlor + fomesafen for the control of Palmer Amaranth (Amaranthus palmeri S. Watson), carpetweed (Mollugo verticillata L.), crabgrass (Digitaria spp.), giant foxtail (Setaria faberi), waterhemp (Amaranthus tuberculatus (Moq.) Sauer), and velvetleaf (Abutilon theophrasti Medik.). Specialty additives increased herbicide weed control from one to six wk after application, but the results for each additive differed with the herbicide active ingredient and weed species. A possible mode of action for the observed enhanced efficacy with the specialty additives may be improved initial placement of the herbicide in the soil profile and increased retention of the herbicide in the soil. These preliminary data provide a valid starting point to further develop several specialty additives for enhancing residual herbicides efficacy to improve season-long weed management.

THE GOOD, THE BAD AND THE UGLY WHEN SPRAYING THE NEW PHENOXY HERBICIDE FORMULATIONS IN ROUNDUP READY XTEND AND ENLIST SOYBEANS. Robert N Klein*; University of Nebraska, North Platte, NE (137)

The Good is that these new phenoxy herbicide formulations will help control tough broadleaf weeds, including resistant and difficult to control weeds in dicamba- and 2,4-D-tolerant soybeans. The Bad is that if not used with a weed management plan, we could quickly lose these new formulations to weed resistance. The Ugly is that if the labels and stewardship are not adhered to, we could have major losses to crops and other vegetation. The new phenoxy herbicide formulations, including Enlist Duo™ (Dow), XtendiMax® (Monsanto), Engenia™ (BASF), and FeXapan™ (DuPont), offer growers new management options along with new application requirements. In the past, we have experienced problems when crops resistant to a particular herbicide were commercialized. For example, when glyphosate-tolerant soybean came to the market in 1996, there were a number of problems with spray drift, primarily to corn. Improved application practices, including spray nozzle selection, were successful in minimizing the application problems. Tim Creger, manager of the Nebraska Department of Agriculture Pesticide/Fertilizer Program, noted on the first year (2017) of dicamba-tolerant soybeans follows: “NDA has received 91 claims of dicamba damage to soybeans, with the last one being received on September 19th.” While it is only an estimate, these reports account for approximately 15,000 acres of damaged soybeans, two vineyards (total of two hectares), and numerous trees (both commercially grown and native). We selected 24 of these reports to conduct active investigations, and were limited to one or two plant samples complaint-1 for laboratory analysis. To date, all but five samples have been reported, with 100% detection of dicamba for samples exhibiting obvious leaf cupping. What is somewhat curious to me is that in those samples collected before July 7th, only dicamba was found, while those collected after July 10th also reported 2,4-D. Volatilization of the dicamba products appeared to be the biggest problem in the first year use of these new products. High temperatures during application and the following d after application without doubt contributed to the injury to conventional and non-dicamba-tolerant soybeans as well as other vegetation.

OPTIMIZATION OF DICAMBA AND GLUFOSINATE APPLICATIONS USING PULSE-WIDTH MODULATION. Thomas R. Butts*1, Chase A. Samples2, Lucas X. Franca2, Darrin M. Dodds2, Dan Reynolds3, Jason W. Adams4, Richard Zollinger5, Kirk A. Howatt4, Greg R Kruger6; 1University of Nebraska-Lincoln, North Platte, NE, 2Mississippi State University, Mississippi State, MS, 3Mississippi State University, Starkville, MS, 4North Dakota State University, Fargo, ND, 5North Dakota State Univ, Fargo, ND, 6University of Nebraska, North Platte, NE (138)

Site-specific pest management strategies provide opportunities to maximize efficacy while simultaneously minimizing negative environmental impacts. Pulse-width modulation (PWM) sprayers can play a crucial role in these site-specific pesticide applications as they are capable of producing and maintaining an optimum droplet size across a field. The objective of our research was to use a PWM sprayer to optimize dicamba and glufosinate applications by determining the droplet size and carrier volume that maximizes efficacy and reduces drift potential. A randomized complete block field study was conducted in 2016 and 2017 across three locations (Mississippi, Nebraska, and North Dakota) for a total of six site-years. Treatments were arranged in a 2 x 6 factorial which consisted of two carrier volumes (47 and 187 L ha-1) and six droplet sizes (150, 300, 450, 600, 750, and 900 µm) determined from the Dv50 of the measured spray solution. The Dv50 parameter represents the droplet size such that 50% of the spray volume is contained in droplets of equal or lesser values. Nozzle type, orifice size, and application pressure required to create each droplet size treatment were determined through droplet size measurements made using a Sympatec HELOS-VARIO/KR laser diffraction system. One nontreated control was used for comparisons which provided a total of 25 treatments. Treatments were applied using a PinPoint® PWM sprayer. Dicamba and glufosinate were applied postemergence (POST) to ≥15 cm tall weeds at labeled rates of 0.28 kg ae ha-1 and 0.45 kg ai ha-1, respectively. In general across site-years, glufosinate efficacy decreased with droplet sizes larger than 450 µm. However, at 47 L ha-1 carrier volume, glufosinate efficacy was greater with droplet sizes larger than 450 µm compared to 187 L ha-1 carrier volume. Dicamba efficacy was relatively unaffected by carrier volume, but 187 L ha-1 carrier volume stabilized weed control across a wider range of droplet sizes than 47 L ha-1. Further, dicamba efficacy was reduced when spray droplet size was larger than 750 µm, indicating there is a critical limit to spray droplet size even for a systemic herbicide. Glufosinate applications were optimized when sprayed at 47 L ha-1 with medium to coarse spray qualities. Dicamba applications were optimized when sprayed with extremely coarse to ultra-coarse spray qualities at either 47 or 187 L ha-1. This research provides critical information for the development of site-specific management strategies with PWM sprayers using dicamba and glufosinate herbicides.

EFFICACY OF DRIFT REDUCING ADJUVANTS (DRA) APPROVED FOR ROUNDUP READY XTEND SOYBEAN. Richard Zollinger*1, Mark Bernards2, Greg R Kruger3, Dallas E. Peterson4, Bryan G. Young5; 1North Dakota State Univ, Fargo, ND, 2Western Illinois University, Macomb, IL, 3University of Nebraska, North Platte, NE, 4Kansas State University, Manhattan, KS, 5Purdue University, West Lafayette, IN (139)

Glyphosate and dicamba are weak acid herbicides and can bind with antagonistic salts in the spray carrier. Diammonium sulfate (AMS) is commonly used as an adjuvant with glyphosate to enhance activity and overcome antagonistic salts. Dicamba use in resistant soybean will restrict addition of AMS due to the formation of dicamba-acid which is more volatile than the formulated salt of dicamba thus increasing risk of injury to nearby susceptible crops. Efficacy studies were conducted to test efficacy of non-AMS water conditioning (WC) adjuvants of diverse active ingredients applied with glyphosate and with dicamba separately. Herbicides were applied at 0.84 and 0.56 kg ha-1, respectively. Some common ingredients in WC adjuvants were carboxylic acid, monocarbamide dihydrogen sulfate (AMADS), dipotassium phosphate, and MSO. Treatments were applied in 1000 ppm hard water created by adding calcium and magnesium in a 75 : 25 ratio to distilled water. Standards for comparison were glyphosate applied alone and with ammonium sulfate (49.4 g L-1 water) each applied in distilled water and in 1000 ppm hard water. Studies were conducted in Illinois, Indiana, Kansas, Nebraska, North Dakota, and Minnesota on several species known to show glyphosate antagonism from hard water, including velvetleaf. Efficacy of nine non-AMS WC adjuvants with glyphosate and dicamba was less than herbicides with AMS. One WC adjuvant that contained MSO was equal. Results may apply to other weak acid herbicides. AMADS (neutralized), dipotassium phosphate (DPP), and MSO contribute to efficacy and/or water conditioning. WC adjuvants overcame or partially overcame hard water antagonism. DPP and AMADS as a substitute for AMS can partially condition water. DPP may condition water through the phosphate anion but the compound is void of nitrogen which may explain why DPP does not exhibit the same level of overcoming mineral and herbicide antagonism as AMS. Sulfuric acid in AMADS is converted to sulfate in water and can condition water only with an adequate rate. Conversion of urea in AMADS to ammonia is slow. Lack of ammonia in WC conditioning adjuvants to drive the proton pump in plants cells may be the cause for lower efficacy.

ASSESSMENT OF COMMERCIAL SCALE DICAMBA DRIFT USING DRIFT REDUCING ADJUVANTS. Ryan J. Edwards*1, Gregory K. Dahl2, Lillian Magidow1, Raymond L. Pigati3, Laura Hennemann4, David Palecek5, Eric Spandl6, Joe V. Gednalske2; 1WinField United, River Falls, WI, 2Winfield United, River Falls, WI, 3WinField United, Shoreview, MN, 4Winfield Solutions, River Falls, WI, 5Winfield, River Falls, WI, 6Winfield Solutions LLC, Shoreview, MN (140)

Off-target dicamba movement has been shown to be reduced when drift reducing adjuvants are added to spray mixtures. OnTargetTM (AG16098) adjuvant is a patent-pending technology specifically designed for ultra and extra coarse nozzles, for use with the new dicamba herbicide chemistries. This adjuvant system has been formulated to reduce driftable fines when using the new dicamba formulations alone or in combination with glyphosate. OnTargetTM was listed as an approved DRA on both the Monsanto and BASF web sites in 2017. A commercial scale sprayer was used to assess the effects of different DRA materials when applied in windy field conditions. Data were collected downwind using repeated horizontal transects, water sensitive spray deposition cards and NDVI images from a fixed wing drone. In all instances where DRA's were not used, off target drift far exceeded tolerable limits imposed by labeled buffer zone restrictions. Conversely, when DRA's were added to a tank-mixture of dicamba and glyphosate, detectable and visible reductions in off-target movement were achieved.

EFFECTS OF SOLUTION VISCOSITY ON DROPLET SIZE. Gabrielle C. Macedo*1, Glen Obear2, Frank Sexton3, Jeffrey Golus1, Jesaelen G. Moraes1, Greg R Kruger4; 1University of Nebraska-Lincoln, North Platte, NE, 2University of Nebraska-Lincoln, Lincoln, NE, 3Exacto, Inc., Sharon, WI, 4University of Nebraska, North Platte, NE (141)

During the application of herbicides, the deposition of the product on non-target organisms should be avoided. The use of nozzles that can produce larger droplets or the addition of adjuvants to the solution are good options for drift reduction. The addition of adjuvants can alter some solution characteristics including droplet size. The objective of this research was to assess the combinations of herbicides with adjuvants on their influence of droplet size. Two studies were conducted at the Pesticide Application Technology Laboratory in North Platte, NE. The first study was conducted in a low-speed wind tunnel using a Sympatec HELOS-VARIO/KR laser diffraction system for droplet measurements. Acifluorfen (12 g ai ha-1) was applied in a mixture with four concentrations of an experimental adjuvant with unique liquid physical properties at 0, 0.2, 0.4, 1 and 3% v v-1, and dicamba was applied at 0, 2, 4, 8, 16 and 32 g ae ha-1 in a mixture with four concentrations of a second experimental adjuvant also containing unique experimental properties at 0, 0.1, 0.5, 1 and 5% v v-1). The solutions were sprayed through two pre-orificed, non-venturi nozzles (ER11004 and DR11004) at 434 kPa to determine spray droplet size. Each nozzle was traversed through the laser beam three separate times to measure the entire spray plume providing three repetitions. The second study was performed using an optical tensiometer, OCA 15EC (DataPhysics Instruments GmbH, Filderstadt, Germany) and a concentration meter DMA 4500 M Chemicals (Anton Paar GmbH, Graz, Austria). For acifluorfen, data were subjected to ANOVA and means were separated using Fisher's Protected LSD test with the Tukey adjustment. For dicamba, data were analyzed using a nonlinear regression model with the drc package in R 3.4.2. For EXT876 and EXT1112, increased adjuvant concentration results in increased droplet size and reduction of the percent fines (<150 µm). For EXT876, the surface tension is reduced with the addition of adjuvant, but without difference between the different concentrations, density is not changed and viscosity increases according to the rate. For EXT1112, the increase in density was due to the increase in dicamba concentration and was not altered with increasing adjuvant concentration, the viscosity increases only at the 5% v v-1 of adjuvant and the surface tension was not changed. When the viscosity is high, at 3% v v-1 using EXT876 or 5% v v-1 using EXT1112, the droplet size decreases but it is always greater than the treatment without adjuvant.

ACCUDROPTM - A NEW DRIFT CONTROL AND DEPOSITION ADJUVANT. Thomas A. Hayden*1, Gregory K. Dahl2, Ryan J. Edwards3, Jo A. Gillilan4, Eric Spandl5, Raymond L. Pigati6, Joe V. Gednalske2, Lillian Magidow3, Andrea Clark3, Daniel C. Bissell7; 1Winfield United, Owensboro, KY, 2Winfield United, River Falls, WI, 3WinField United, River Falls, WI, 4Winfield United, Springfield, TN, 5Winfield Solutions LLC, Shoreview, MN, 6WinField United, Shoreview, MN, 7Winfield United, River Fall, WI (142)

AccuDrop™ is a non-oil, surfactant based drift and deposition adjuvant formulated without nonylphenol ethoxylates. AccuDrop™ is designed to maximize pesticide performance by improving spray deposition onto the intended target. Also, being surfactant based, AccuDrop™ can be used with many herbicides, fungicides or insecticides with minimal expected crop injury. The use rate of AccuDrop™ is 0.223 L ha-1. As part of the testing program, 126 field efficacy trials were conducted as well as screening though a recirculating low speed wind tunnel. In numerous field trials, herbicide plus AccuDrop™ performance versus the herbicide alone showed increased weed control. Field drift studies also showed drift reductions; 3.02 m with the addition of AccuDrop™ compared to 6.83 m with no drift control added. Wind tunnel testing was utilized to evaluate spray particle size with various pesticides and nozzle tips. AccuDrop™ added to glyphosate and sprayed through XR11003 nozzles reduced the percent of spray particle droplet fines from 16% to 6%. Likewise, with an AIXR 11004 nozzle, percent fines were reduced from 16% to 4% vs glyphosate alone.

RAINFASTNESS OF XTENDIMAX, ROUNDUP XTEND, CLARITY AND ROUNDUP POWERMAX ON WEED CONTROL. Andre O. Rodrigues*1, Ryan Rector2, Ulisses R. Antuniassi3, Cody Creech4, Lucas X. Franca5, Bradley K. Fritz6, Greg R Kruger7; 1University of Nebraska-Lincoln, North Platte, NE, 2Monsanto Company, St. Charles, MO, 3UNESP, Botucatu, Brazil, 4University of Nebraska-Lincoln, Scottsbluff, NE, 5Mississippi State University, Mississippi State, MS, 6ARS-USDA, College Station, TX, 7University of Nebraska, North Platte, NE (143)

Herbicide performance and physiology and growth of plants are affected by environmental conditions. Among environmental factors, rain shortly after herbicide application can be one of the most detrimental factors to the performance of a herbicide. Rainfastness of a herbicide is related to the rate of absorption and the time it takes for the droplet to dry on the leaf surface. Rainfall after herbicide application results in a wash off effect, where part or all of the deposited herbicide is washed off the plant without getting absorbed. A greenhouse study was conducted at the University of Nebraska – Lincoln at the West Central Research and Extension Center (UNL-WCREC) in North Platte, NE on the following weed species: velvetleaf (Abutilon theophrasti Medik), Palmer amaranth (Amaranthus palmeri S. Wats), morningglory (Ipomoea spp.), grain sorghum (Sorghum bicolor (L.) Moencch subsp. Bicolor). Species were selected based on their availability, leaf surface type, plant structure, greenhouse growth characteristics, and diversity across weed species. Four herbicides were tested: XtandiMax®, Xtend®, Clarity® and Roundup PowerMax®. XtendiMax® and Clarity® were tested alone and in tank-mixtures with Roundup PowerMax®, while Xtend® were just tested alone. Herbicide treatments were applied at Xtendimax (1,117 g ae ha-1 and 558 g ae ha-1), Roundup PowerMax (1,262 g ae ha-1 and 631 g ae ha-1), Clarity (1,120 g ae ha-1 and 560 g ae ha-1), Roundup Xtend (2,244 g ae ha-1 of glyphosate and 1,122 g ae ha-1 of dicamba, and also 1,122 g ae ha-1 of glyphosate and 561 g ae ha-1). Rainfall simulation was conducted after application in intervals of 0.5, 1, 2, 4, 8 hr after application (HAA). A no rainfall treatment was included. A spray chamber at the PAT Lab was used to apply 6 mm of water. Herbicide treatments were made when weed species were 10- to 15-cm tall using 94

L ha-1 at 24 km hr-1 and 434 kPa through a TTI11004 nozzle. Plants were sprayed in a three-nozzle track spray chamber with nozzles spaced 50 cm apart and plants located 50 cm below the nozzles. After herbicide treatments rainfall simulation was applied using a single-nozzle track sprayer using a HF 140-15 nozzle for six min at 3 km hr-1. Visual estimations of injury were collected at 28 d after treatment (DAT), the estimations ranged from 0-100, where 0 is no control and 100 is complete plant death. At 28DAT, plants were harvested at the soil surface, plants were dried to constant mass, and dry weights were recorded. A reduction in control was observed in velvetleaf when rainfall was within 4HAA, for Palmer and grain sorghum there was no reduction in control with rainfall after application. Therefore, wash off effect is dependable on leaf surface and structure varying from species to species.

RELATIVE VOLATILITY OF AUXIN HERBICIDE FORMULATIONS. Jerome J. Schleier*, David Ouse, James Gifford, Suresh Annangudi Palani; Dow AgroSciences, Indianapolis, IN (144)

Crops with traits that provide tolerance to 2,4-D or dicamba have been developed. Volatility of 2,4-D and dicamba is generally directly correlated to the volatility of the associated counter-ion. Laboratory and field studies conducted demonstrate that the non-volatile choline provides a reduction in volatility of 2,4-D even compared to the dimethylammonium (DMA) salt. Similarly, BASF has shown reduction in volatility with the N,N-Bis-(3-aminopropyl)methylamine (BAPMA) salt of dicamba compared to the DMA salt. Applications of tank-mixtures and pre-mixtures of dicamba or 2,4-D with glyphosate or other pesticides for broad-spectrum pest control are and will continue to be a preferred option for growers. In addition, applications will often include the addition of water conditioning agents such as ammonium sulfate (AMS) or AMS replacements. It is important to understand the impact of spray solution properties on the volatility of auxinic herbicides from plant and soil surfaces. The effect of herbicide salt, glyphosate, spray solution pH, and the presence of various counter-ions on the volatility of dicamba and 2,4-D were determined in controlled laboratory studies. Based on findings from these studies a new dicamba formulation with reduced volatility has been developed and is being characterized.

THE INFLUENCE OF PUMP SHEARING ON THE DROPLET SPECTRUM OF SPRAY MIXTURES CONTAINING DICAMBA, GLYPHOSATE AND VARIOUS DRIFT REDUCTION AGENTS. Daniel Bissell1, Andrea Clark1, Raymond L. Pigati*2, Joe V. Gednalske3, Lillian Magidow1, Gregory K. Dahl3; 1WinField United, River Falls, WI, 2WinField United, Shoreview, MN, 3Winfield United, River Falls, WI (145)

With the recent introduction of new dicamba herbicide formulations there has been an increased focus and demand for a category of adjuvants called Drift Reducing Adjuvants (DRAs). Most current DRAs are polyacrylamide or polysaccharide based and are required to be included into the spray application solution when a new dicamba herbicide formulation is tank-mixed with certain products. The new DRA requirement was initiated to maintain the volume fraction of driftable droplets (≤ 150 µm) produced during a spray application to equal to or less than when a new dicamba formulation is applied alone. To determine susceptibility to shear, three DRAs were exposed to a pumping system and the volume fraction of the driftable droplets was measured after a specific number of passes through the pumping system. Samples were collected after 0, 10, 25, and 50 passes through a closed-loop pumping system. The samples were then sprayed and measured in a low speed wind tunnel. At zero passes, all DRAs reduced the volume fraction of driftable droplets compared to the tank-mixture of dicamba and glyphosate alone. As passes through the closed-loop pumping system increased, the polyacrylamide products failed to reduce the driftable droplet reduction, however the polysaccharide DRA continued to reduce the volume fraction of driftable droplets after all passes through the pumping system. This data concludes that polyacrylamide DRAs could begin to lose the ability to reduce driftable droplets after passing thorough a pump in an agricultural sprayer.

INVESTIGATION OF NOZZLE EROSION FROM COMMERCIAL APPLICATION EQUIPMENT; THE SECOND YEAR. Andrea Clark, Lillian Magidow, Ryan J. Edwards*; WinField United, River Falls, WI (146)

In 2015, a commercial sprayer was outfitted with an entire boom of new AIXR11005 spray nozzles to measure nozzle erosion throughout a single spray season as well as a year-to-year effect. Nozzles were subjected to three preliminary tests: 1) measuring flow rate with a volumetric container and stop watch, 2) measuring the area of the nozzle orifice with a Dyno-Lite Digital Microscope and 3) measuring droplet size, specifically investigating droplets below the size of 105 microns (µm), using laser diffraction to determine droplet size. Nozzles on two sections of the boom were changed out annually to measure nozzle erosion within a given season. Another two sections of nozzles were replaced year after year to measure cumulative erosion effects when nozzles are not changed out in a timely manner. After the first spray season, nozzles were retested via the testing matrix described. Notable changes were seen in VMD, percentage of volume of spray under 105 µm, and flow rate after one spray season. The same commercial sprayer was again outfitted with four boom sections of new nozzles in 2016 to show a new season's worth of wear, and four boom sections of the previously used nozzles to continue measuring multi-year, cumulative erosion. This presentation will continue from the previous year, comparing what happened between two spray seasons from an annual change perspective and a two-year cumulative perspective.

NOZZLE SELECTION AND ADJUVANT IMPACT THE EFFICACY OF GLYPHOSATE AND PPO-INHIBITING HERBICIDE TANK-MIXTURES. Milos Zaric*1, Jesaelen G. Moraes1, Andre O. Rodrigues1, Debora O. Latorre1, Bruno Canella Vieira2, Greg R Kruger3; 1University of Nebraska-

Lincoln, North Platte, NE, 2University of Nebraska, Lincoln, NE, 3University of Nebraska, North Platte, NE (147)

The use of glyphosate and PPO-inhibiting herbicide tank-mixtures is one of the few current remaining alternatives for soybean growers to manage glyphosate resistance since the number of effective post-emergence herbicides options are limited. How those herbicides and adjuvants interact as well as the droplet size produced from these tank-mixtures have not been investigated thoroughly. The objectives of our research were to evaluate any possible interaction and to determine the impact of nozzle selection and adjuvants on the efficacy of these herbicide modes of action in tank-mixtures. Field studies were conducted as a randomized complete block design with a factorial arrangement of treatments in two different fallow fields infested with Palmer amaranth (Amaranthus palmeri S. Watson) located near Beaver City, NE, and a greenhouse study was conducted as a completely randomized factorial design located in UNL-WCREC in North Platte, NE, using two species: horseweed (Conyza canadensis (L.) Cronq.) and grain sorghum (Sorghum bicolor (L.) Moench subsp. Bicolor). Fomesafen (130 g ai ha-1), lactofen (220 g ai ha-1) and glyphosate (1120 g ae ha-1) were applied both either alone and in combination using 1X rates for the field studies and 0.5X rates in the greenhouse study, respectively. COC 1% v v-1 was used in all treatments containing fomesafen or lactofen. In the greenhouse study, fomesafen treatments were exluded; however, NIS 0.25% v v-1, MSO 1% v v-1, and drift retardant 0.5% v v-1 were included in the treatments. Each treatment was applied at 187 L ha-1 with 276 kPa using a CO2 sprayer mounted to a Bobcat 3400 UTV with a four nozzle boom (in the field) or a three nozzle laboratory track sprayer (in the greenhouse study). In total, three nozzle types (XR, AIXR, and TTI) with the same orifice size (11004) were used. Visual estimations of injury were collected at 7, 14, 21 and 28 d after application (DAA) and dry weights were recorded for the greenhouse trial. Furthermore, droplet size distribution were measured using a low-speed wind tunnel. Data were subjected to ANOVA and means were separated using Fisher's Protected LSD test with the Tukey adjustment. The solution by species interaction was significant for the control of species whereas the nozzle effect was not significant. The nozzle by solution interaction had a significant impact on the percent of fine droplets (<150 µm) produced. Particularly when glyphosate was used alone in combination with the XR nozzle. Antagonistic interactions were observed in specific treatments in both greenhouse and field studies. Herbicide efficacy was affected by both treatment and species. Droplet size was influenced by both spray solution and nozzle selection. Recommendations should be based on specific weed species to optimize spray applications. In some cases tank-mixtures may not be advisable because antagonistic effects can occur. Larger droplets would be recommended to minimize the drift potential of the spray application.

SELECTED ADJUVANTS ENHANCE WEED CONTROL WITH GLUFOSINATE-AMMONIUM IN COLORADO AND SOUTH DAKOTA. Jim Daniel1, Eric Westra*2, Paul Johnson3, Phil Westra4; 1Jim T Daniel, Keenesburg, CO, 2Colorado State University, Fort Collins, CO, 3South Dakota State University, Brookings, SD, 4Colorado State Univ, Ft Collins, CO (148)

Glufosinate-ammonium is a Group 10 postemergence herbicide used in non-crop situations and in glufosinate-tolerant crops. It has greater, more consistent use in the Midwest US than on the High Plains and western US. Use of new adjuvants could potentially improve the control and consistency of glufosinate in these areas. A series of trials were conducted to evaluate the impact of several adjuvants on glufosinate weed control. These trials consisted of three greenhouse studies conducted at Colorado State University, as well as three field studies conducted in Colorado, and one field trial conducted in eastern South Dakota. Across these trials, five candidate adjuvants were compared with the manufacture suggested adjuvant of 3.37 kg ha-1 ammonium sulfate plus 0.5% v v-1 nonionic surfactant. The candidate adjuvants performed as well as or better than the standard. AQ 127 at 0.375% v v-1 provided more control than other adjuvants tested. The addition of 1.68 kg ha-1 ammonium sulfate improved control over the adjuvants alone. Results suggest that the use of candidate adjuvants over currently used adjuvants could help improve weed control with glufosinate-ammonium.

PARAQUAT EFFICACY AS INFLUENCED BY SPRAY DROPLET SIZE FOR PALMER AMARANTH CONTROL. Marshall M. Hay*1, Dallas E. Peterson1, Greg R Kruger2, Thomas Butts3; 1Kansas State University, Manhattan, KS, 2University of Nebraska, North Platte, NE, 3University of Nebraska-Lincoln, North Platte, NE (149)

Paraquat use has increased in recent years for burndown and fallow control of glyphosate-resistant Palmer amaranth. With the recent reduction in paraquat price, many producers are considering the use of paraquat; however, very little is understood about paraquat spray characteristics to optimize the control of Palmer amaranth while minimizing the potential for spray drift. The objective of this research was to understand the influence of different droplet spectrums on paraquat efficacy on Palmer amaranth. The research was conducted with a reduced rate of paraquat (100 g ai ha-1) applied with 0.25% v v-1 non-ionic surfactant at a spray volume of 187 L ha-1. Wilger spray nozzles were used in all treatments. Droplet spectrum for nozzle and pressure combinations with the same paraquat spray solution were assessed in a low speed wind tunnel using laser diffraction at the University of Nebraska-Lincoln Precision Application Technology Lab in North Platte to determine the appropriate nozzle sizes and pressures to achieve target droplet spectrums of 200, 300, 450, 600, 750, and 900 Dv50 (µm). A tractor mounted four nozzle boom equipped with a pulse-width modulation system was operated at 6.6 km hr-1 for treatments. Applications were made to actively growing 10 cm Palmer amaranth in Riley and Sedgwick Counties in Kansas in August of 2017 and visual ratings and weed counts were taken 14 d after treatment. At both locations, the greatest efficacy and highest reduction in weed counts were observed with the 200 and 300 Dv50 treatments; whereas when the Dv50 was greater than 300 µm, control and reduction in weed counts tended to decrease. When comparing the percentage of the total spray volume (% vol) that was in droplets less than 141 µm, the 200 Dv50 treatment contained 26.7% vol whereas the 300 Dv50 treatment only contained 8.3% vol. The results of this research indicate that droplet spectrum is important for paraquat efficacy in Palmer amaranth, and that spray applications should be made with Dv50 values between 200 µm and 300 µm to minimize the number of droplets less than 141 µm.

A QUALITATIVE ASSAY FOR DETECTING PALMER AMARANTH AND ITS HYBRIDS AMONGST PIGWEED SPECIES. Maxwel C. Oliveira*1, Eric Patterson2, Todd A. Gaines2, Stevan Z. Knezevic1; 1University of Nebraska-Lincoln, Concord, NE, 2Colorado State University, Fort Collins, CO (150)

Pollen-mediated gene flow is an important factor of rapid adaptive evolution and may play the part of an important role in dispersing herbicide-resistant alleles in obligate outcrossing dioecious pigweed species. Field experiments were conducted in Concord, NE, US to quantify interspecific (Palmer amaranth × waterhemp) gene flow study in a concentric donor-receptor design and to develop a molecular marker that differentiates Palmer amaranth, waterhemp, and their hybrids. Interspecific hybridization was evaluated using a resistant waterhemp phenotype with enhanced mesotrione detoxification via cytochrome P450 as a source of resistant alleles. Over 104,000 suspect hybrid seedlings were sprayed with herbicide (175 g ai ha-1 mesotrione). Then, survived plants (suspected hybrids) were screened with two molecular assays using KASP (Kompetitive Allelic Specific PCR). The first molecular marker was a single nucleotide polymorphism (SNP) in the acetolactate synthase (ALS) region of Palmer amaranth and waterhemp. The novel molecular marker was a double SNP in the internally transcribed spacer (ITS) region which distinguishes Palmer amaranth and its hybrids from eight weedy pigweed species commonly found in the US. Results showed that our overall estimation detected 0.1% hybridization between Palmer amaranth and waterhemp, and hybrids were found up to 15 m from the pollen-source block. This result is the first report of metabolism-based resistance transfer in pigweed species. Results presented here will aid in the rapid identification of Palmer amaranth among other pigweed species, and help to understand the dramatic increase of herbicide-resistant traits in Palmer amaranth and waterhemp populations in the US.

POTENTIAL INFESTATION RISK OF PALMER AMARANTH IN IOWA: SOCIAL AND BEHAVIORAL FACTORS. Maggie Long*1, Leslie Decker1, Marisa DeForest1, Zoe Muehleip1, Geoff Converse1, Drew Roen1, Jacob Bruns1, Clint Meyer1, John Pauley1, Brady Spangenberg2; 1Simpson College, Indianola, IA, 2BASF, Raleigh, NC (151)

Palmer amaranth (Amaranthus palmeri) is a relatively recent invasive weed found in Iowa. Initially, the weed spread slowly in agricultural areas, but contamination of conservation plantings has increased the rate of spread. We sought to estimate the potential risk of Palmer amaranth infestation throughout the state based on what we considered demographic factors: those characteristics that were driven by management decisions or other elements that could be controlled. We conducted over two dozen interviews with agricultural stakeholders (e.g., producers, extension professionals, weed scouts, weed commissioners) to identify sociological and behavioral practices that might impact Palmer amaranth infestation risk. Through the interviews and extensive literature searches, we assigned values to each practice based on whether it would mitigate or exacerbate Palmer amaranth infestation. Mitigating factors included diverse herbicide programs, maintaining ditches, owned equipment (vs. shared), cleanliness of equipment, community collaboration, and Palmer amaranth awareness. We also considered the following attributes that would likely be related to the mitigating factors: average farm expense, farming as primary occupation, CRP acres, percent of farm owned (vs. rented land), average farm size, average income, and average farmer age. We then gathered information from the US Census of Agriculture to quantify these demographic factors to compute potential Palmer amaranth risk for each county. The risk map for demographic factors identified areas of concern throughout the state, especially within south-central and northeastern counties of Iowa. Our results could be used to motivate stakeholders to consider Palmer amaranth when making management decisions, particularly in areas that we identified as having a high potential infestation risk.

POTENTIAL INFESTATION RISK OF PALMER AMARANTH IN IOWA: EDAPHIC AND CLIMATOLOGICAL FACTORS. Leslie Decker*1, Maggie Long1, Marisa DeForest1, Josh Dietrich1, Drew Roen1, Geoff Converse1, Zoe Muehleip1, Jacob Bruns1, Clint Meyer1, John Pauley1, Brady Spangenberg2; 1Simpson College, Indianola, IA, 2BASF, Raleigh, NC (152)

Palmer amaranth (Amaranthus palmeri) is a noxious weed that has been recently found in Iowa. Because of its highly competitive nature, it has the potential to impact agricultural productivity in important ways. We used geographical data to assess how Palmer amaranth infestation risk throughout Iowa is affected by natural conditions (e.g., soil and climate) that cannot be changed. Specifically, we used QGIS layers with the following location-specific data to construct our geographic model: corn suitability rating (CSR2), average maximum temperature, elevation, average annual precipitation, and average wind potential. We then used Quadratic Discriminant Analysis (QDA), which is a supervised machine learning method, to predict locations of Palmer risk based on these geographic factors. The geographic risk map suggests that the southeastern counties near the Mississippi River and the counties that border the Missouri River are at particularly high risk. We then created a synthesis map with this geographic data as well as demographic data we had already compiled and analyzed. The synthesis risk map suggests that Palmer amaranth infestation risk is especially high within the eastern quarter of the state. These results can provide important management information by focusing attention on areas that may have the highest potential for infestation. Future work should focus on collecting additional site-specific information on Palmer amaranth locations to help adjust data to create a more accurate map of Palmer amaranth infestation risk throughout Iowa.

THE POTENTIAL ECONOMIC IMPACT OF PALMER AMARANTH INFESTATION IN IOWA. Jacob Bruns*1, Drew Roen1, Geoff Converse1, Maggie Long1, Leslie Decker1, Marisa DeForest1, Josh Dietrich1, Zoe Muehleip1, Clint Meyer1, John Pauley1, Brady Spangenberg2; 1Simpson College, Indianola, IA, 2BASF, Raleigh, NC (153)

Palmer amaranth (Amaranthus palmeri) represents a serious economic problem for the state of Iowa. To predict the degree of impact of Palmer amaranth in Iowa, we assembled a dynamic economic risk model. Using published yield loss data and a projected microeconomic farm finance model, we created an economic impact study that could provide insight into comprehensive revenue loss and project the potential revenue losses for individual hectares in production. The economic impact model has the capability to react to changes in a multitude of numerical inputs, from per unit crop prices to fixed and variable farm expenses. Using a combination of qualitative and quantitative data, we created models to estimate potential risk of infestation for both geographic and demographic data. The two synthesized risk models identified the most vulnerable hectares in the state. We combined those results with the economic impact model to provide hectare by hectare potential yield loss estimates due to the infestation of Palmer amaranth. Using current yield projection and input cost estimates, a comprehensive yearly revenue figure for the state of Iowa was derived from the economic impact study. When we combined revenue data with county-by-county corn hectares and the most conservative projection of Palmer amaranth infestation density, the revenue loss was over US$1 billion in a single growing season due to Palmer amaranth infestation in the state of Iowa. These results indicate that the threat Palmer amaranth poses to the state of Iowa has the capacity for unprecedented levels of yield and revenue loss.

APPLICATION TIMING OF PPO-INHIBITOR HERBICIDES INFLUENCES LEVEL OF PALMER AMARANTH CONTROL. Anita Dille, Dallas E. Peterson, Larry Rains*; Kansas State University, Manhattan, KS (154)

Application timing is critical for acceptable Palmer amaranth (Amaranthus palmeri) control with postemergence PPO-inhibitor herbicides, but rapid growth rates of Palmer amaranth makes timely applications difficult. A field experiment was conducted in 2016 and repeated in 2017 at the Department of Agronomy Ashland Bottoms Research Farm near Manhattan, KS, to evaluate application timing of PPO-inhibitor herbicides for Palmer amaranth control. The experimental design was a split-plot with four replications and a non-treated control in a no-crop situation. Main plots were seven application timings and subplots were three herbicides. Application timings were applied in three d intervals for 18 d starting when average height of Palmer amaranth was three cm. First application was 7/10/2016 and 5/25/2017. Palmer amaranth height was recorded prior to each herbicide application. Three herbicides and rates were acifluorfen (426 g ha-1), fomesafen (280 g ha-1), and lactofen (224 g ha-1). Herbicide treatments were applied in 140 L ha-1 spray solution in combination with methylated seed oil at 1% v v-1 and urea ammonium nitrate at 2.3 L ha-1. Visual estimation of Palmer amaranth control was recorded on a scale of 0 to 100% two wk after each application. By 18 d after initial application, Palmer amaranth grew to 37- and 73-cm tall in 2016 and 2017, respectively. This corresponds to a growth rate of 2.3 and 3.5 cm d-1 in 2016 and 2017, respectively. There was no interaction of application timing and herbicide on Palmer amaranth control. In 2016 and 2017, treatments applied by d three after the initial application resulted in 95% or greater control and if applied on d six, control was less than 87%. Treatments applied nine d after initial application resulted in 59% or less control in 2016 and 2017. Poor Palmer amaranth control occurred if herbicides were not applied within three d after Palmer amaranth reached 3-cm tall. Palmer amaranth control was not different among herbicides in 2017, however in 2016 acifluorfen provided greatest Palmer amaranth control averaged across application timings. Due to the fast growth rates of Palmer amaranth, early applications are required to achieve highest efficacy.

ONE IN A MILLION? EMPIRICAL DETERMINATION OF MUTATION FREQUENCY FOR HERBICIDE RESISTANCE. Federico Casale*, Patrick Tranel; University of Illinois, Urbana, IL (156)

As a predictable evolutionary process, herbicides select for adaptive alleles, which allow weed populations to survive. These resistance alleles may be available immediately from the standing genetic variation within the population, or may immigrate via pollen or seeds from other population. Moreover, because all natural populations are constantly loaded with mutant genotypes by de novo mutations, resistant mutants may arise spontaneously in any herbicide-sensitive weed population. Recognizing that the relative contribution of each of these three sources deeply affects what strategies should be applied to counteract herbicide-resistance evolution, we aimed to provide experimental information to the resistance evolutionary framework. In this sense, the objective of this experiment is to calculate the de novo mutation rate conferring herbicide resistance in a natural plant population and, additionally, test the hypothesis that the rate increases when plants are stressed by sub-lethal exposure to herbicides. We developed grain amaranth and resistance to ALS herbicides as a model system, enabling the screening of millions of individuals. After screening 70 million seedlings, no mutants resistant to ALS inhibitors were identified. This recovery rate (<1 in 70 million) is lower than expected from theoretical calculations based on previous studies, setting a lower probability of herbicide-resistant mutants to arise spontaneously in natural plant populations. In addition, we found no evidence that herbicide stress increased the mutation rate.

CRITICAL PERIOD OF GRASS WEED CONTROL IN GRAIN SORGHUM. Jeffrey J. Albers*, Dallas E. Peterson, Marshall M. Hay, Anita Dille; Kansas State University, Manhattan, KS (157)

Grain sorghum is an important crop in Kansas and the Great Plains. The major yield limiting factor in these cropping systems is moisture and the second greatest limiting factor is often weed competition. Moisture limitation is often addressed using no-till cropping; however, this creates the need for herbicidal-weed control. ALS-resistant grain sorghum provides an opportunity for post grass control, however, application timing for best management practices is not understood. To address the importance of application timing, a critical period of weed control (CPWC) concept has been developed for other crops. During this CPWC the crop must be maintained weed-free to prevent yield loss. Field experiments were conducted in 2017 near Manhattan, Hays, and Hutchinson, KS to determine the CPWC for grass weed competition in grain sorghum. Each site provided a different grass species community: only giant foxtail (Setaria faberi) occurred in Manhattan, a mixed community of, green (Setaria viridis) and yellow foxtail (Setaria pumilla), barnyardgrass (Echinochloa crus-galli), large crabgrass (Digitaria sanguinalis), and longspine sandbur (Cenchrus longispinus) occurred in Hays, and only large crabgrass occurred in Hutchinson. A total of ten treatments were established in a randomized complete block design with four replications at each location. Four treatments were kept weed-free until 2, 3, 5, and 7 wk after crop emergence, after which grass weeds could grow and compete with the grain sorghum. Four treatments had no weed control until 2, 3, 5, and 7 wk after crop emergence, when weeds were removed, and plots were kept weed-free for the duration of the season. The remaining two treatments were maintained weed-free all season or weedy all season as checks. Weekly measurements included grass weed density and height. Weed removal was achieved with a directed application of glufosinate (449 g ha-1) with a hooded sprayer. Weed biomass was collected with a 0.5 m2 quadrat at each removal timing and a final collection occurred at mid-bloom. At physiological maturity grain was harvested and moisture adjusted to 14.5%. Yields were transformed into percent of weed free yield; then weed-free and weed removal treatments were regressed separately. Treatments did not influence grain yield at Hays or Hutch. This is most likely due to high fertility and adequate moisture received during the season at Hays, and high fertility without season-long weed emergence at Hutch. At Manhattan the weed-free all season yielded 3670 kg ha-1 and giant foxtail competition all season reduced yield by 43%, yielding 1715 kg ha-1.

MODELING EMERGENCE PATTERN OF COMMON RAGWEED INFLUENCED BY SPRING TILLAGE IN NEBRASKA. Ethann R. Barnes*1, Rodrigo Werle1, Lowell Sandell2, John Lindquist3, Stevan Z. Knezevic4, Peter H Sikkema5, Amit Jhala1; 1University of Nebraska-Lincoln, Lincoln, NE, 2Valent, Lincoln, NE, 3University of Nebraska, Lincoln, NE, 4University of Nebraska-Lincoln, Concord, NE, 5University of Guelph, Ridgetown, ON (158)

Spring tillage is a component of an integrated weed management strategy for control of early emerging glyphosate-resistant weeds such as common ragweed; however, the effect of tillage on common ragweed emergence pattern is unknown. The objectives of this study were to evaluate whether spring tillage during emergence would influence the emergence pattern or stimulate additional emergence of common ragweed and to characterize common ragweed emergence in southeast Nebraska. A field experiment was conducted for three years (2014 to 2016) in Gage County, Nebraska in a field naturally infested with glyphosate-resistant common ragweed. Treatments consisted of a no-tillage control and three spring tillage timings. The Soil Temperature and Moisture Model (STM2) software was used to estimate soil temperature and moisture at a 2-cm depth. The Weibull function was fit to total common ragweed emergence (%) with d of year (DOY), thermal time, and hydrothermal time as independent variables. Tillage treatments and year had no effect on total common ragweed emergence (P = 0.88 and 0.35, respectively) and time to 10, 25, 50, 75, and 90% emergence (p = 0.31). However, emergence pattern was affected by year (p = <0.001) with 50% total emergence reached on 5/5/2014, 4/20/2015, and 4/2/2016 and 90% total emergence reached on 5/12/2014, 5/8/2015, and 4/30/2016. According to the corrected information-theoretic model comparison criterion (AICc), the Weibull function with thermal time and base temperature of 3 C best explained the emergence pattern over three years. This study concludes that spring tillage does not stimulate additional emergence; therefore, after the majority of the common ragweed has emerged and before the crop has been planted, tillage could be used as an effective component of an integrated glyphosate-resistant common ragweed management program in Nebraska.

POST-DISPERSAL SEED FATE AND TIME OF EMERGENCE OF JOHNSONGRASS IN NEBRASKA. Don Treptow*1, Rodrigo Werle2, Amit J. Jhala2, Melinda Yerka2, Brigitte Tenhumberg1, John Lindquist3; 1University of Nebraska - Lincoln, Lincoln, NE, 2University of Nebraska-Lincoln, Lincoln, NE, 3University of Nebraska, Lincoln, NE (159)

Understanding Johnsongrass post-dispersal seed fate and seedling emergence window is necessary for modeling population dynamics in response to management strategies (e.g., crop rotation and herbicide programs). Johnsongrass fall and spring seed predation and decay, seed winter survival, seedling emergence window, and growing season seed survival of multiple populations were examined at two locations across two growing seasons in Nebraska. The field experiments were conducted at the UNL – Agricultural Research and Development Center near Mead, NE and at the UNL – Havelock Farm, Lincoln, NE during 2016/2017 and 2017/2018. The study was conducted as a two-way factorial on a completely randomized design with four replications. Johnsongrass populations (total of nine) and predation basket type were the two main factors. Seed populations from Johnsongrass subjected to different herbicide treatments in Nebraska along with seeds collected from different cropping systems (e.g., corn, grain sorghum, fallow, and soybeans) throughout Kansas, Missouri and Nebraska were used for this experiment. In the fall after collection, the seeds from all populations were tested for viability using a germination chamber and the tetrazolium seed test procedure. Mesh baskets were buried in the fall and 200 seeds of each population were placed on the soil surface of each basket. Predation baskets went without lids while non-predation baskets had mesh lids on to exclude predators. Predation and non-predation baskets were collected either in early January or early April to assess fall and spring seed predation and decay as well as seed winter survival. Seeds were retrieved from the baskets by washing them from the soil, counted, and tested for viability as previously described. Another set of non-predation baskets had lids removed in early April and Johnsongrass emergence was recorded weekly throughout the growing season. These baskets were collected in mid-September and ungerminated seeds were retrieved and are being tested for viability. The data collected from this project and additional projects evaluating Johnsongrass rhizome demographics will be used as parameter values for a herbicide resistance risk-assessment model simulating Johnsongrass population dynamics under different crop rotations and herbicide programs.

INTERSEEDING COVER CROPS TO SUPPRESS WEEDS IN KENTUCKY CORN-SOYBEAN ROTATIONS. Tori Stanton*, Erin Haramoto, Tim Phillips; University of Kentucky, Lexington, KY (160)

Cover crops are known to suppress weed emergence but the typical approach to planting leaves the system susceptible to weed emergence directly after the main cash crop harvest. Interseeding cover crops into a standing cash crop may limit the time soil is bare after harvest by allowing cover crops to become established, go into dormancy, and then revive around cash crop harvest in the fall. A study was conducted in Princeton, KY, to determine if the establishment of interseeded cover crops was impacted by a soil residual herbicide applied at corn planting and to see if interseeded annual ryegrass or orchardgrass cover crops suppressed weeds better than cereal rye planted post harvest (PH rye; i.e. standard practice). A soil residual herbicide containing three active ingredients (s-metolachlor + mesotrione + atrazine) was applied at three different rates (0 : 0 : 0, 0.73 : 0.09 : 0.73, 1.21 : 0.16 : 1.21 kg ha-1) at corn planting. Annual ryegrass and orchardgrass were interseeded when the corn was between V5-V7. Cover crop density was measured 14 d after planting in 2016 and 50 d after planting in 2017. Weed density and biomass in 2016 and weed biomass in 2017 were measured before corn harvest. Weed density and biomass and cover crop density and biomass were measured again before cover crop termination in the spring. Early cover crop density shows that establishment of the interseeded cover crops was not impeded by any soil residual herbicide rate. This could be due to rainfall between application of the herbicide and interseeding the cover crops limiting the effectiveness of the soil residual herbicide. Interseeded cover crops did not result in lower weed biomass or weed density at corn harvest compared to the control. The following spring, the PH rye had more biomass than either interseeded cover crop; there was also lower weed biomass in this treatment. Between the two interseeded treatments, orchardgrass had the highest density at termination. Weed biomass for the control and the two interseeded treatments was the same at termination. The potential benefits of interseeding (lower weed biomass and weed density at harvest and at termination) were not seen possibly because of low summer survival of the interseeded cover crops. In this study, interseeded cover crops did not result in better weed control compared to post harvest planted rye.

EFFECTS OF FAILED COVER CROP TERMINATION AND WINTER ANNUAL WEED SUPPRESSION IN THE EASTERN CORNBELT. Stephanie DeSimini*1, Bill Johnson2; 1Purdue University, West Lafayette, IN, 2Purdue University, W Lafayette, IN (161)

The recent interest in cover crops as an addition to corn and soybean production systems in the Midwest has led to a greater need for research of cover crops. It is important to understand the benefits for weed suppression and to understand how termination timing can influence the planting of a desired cash crop. Previous research has shown that some cover crop species can reduce end of season cash crop yields if not terminated successfully. Reports in 2015 suggested an increase of glyphosate-tolerant canola seed contamination in cover crop mixtures in Indiana. Controlling these volunteers is an area of concern for Indiana growers. A field experiment was conducted in 2016 to evaluate early spring weed suppression, and to quantify how a late termination of cover crops can effect end of season cash crop yield. The cover crops used in this field experiment were cereal rye and traditional hybrid winter hardy canola mixed with glyphosate-tolerant canola. Cereal rye was selected for it’s rapidly accumulating aboveground biomass and winter hardiness. Canola has been recommended for similar benefits as a cover crop. To simulate a seed contamination event, traditional winter hardy canola was mixed with 0.03% glyphosate-tolerant canola. Cereal rye and canola were planted on 9/21/2016 at the Throckmorton Purdue Agricultural Center near West Lafayette, IN and the Southeast Purdue Agricultural Center in Butlerville, IN. Herbicide treatments were applied at an early and late termination timing the following spring. Early termination was three wk before plant (WBP), and the late termination was three WAP. Visual estimations of control and above-ground biomass reduction were determined 28 d after application (DAA). Weed densities were recorded in the fall, spring, and summer. Corn and soybeans were harvested October 31 and November 7, respectively. In general, plots with cereal rye terminated early yielded higher than plots with cereal rye terminated late. There was no difference in corn yield from plots with cereal rye terminated early and plots with no cereal rye. Late terminated rye resulted in 605 fewer kg ha-1 of corn than early terminated cereal rye or no cover crop. Soybean yield was greater in plots where cereal rye was terminated early compared no cover crop and cereal rye terminated late. Late terminated cereal rye resulted in 336 fewer kg ha-1 than early termination or no cover crop. Corn following early or late canola termination had no major differences in yield compared to areas with no cover crop. Late terminated canola resulted in 134.5 fewer kg ha-1 than early termination or no cover crop. There were no differences in weed control between cover crop plots using herbicide treatments, and herbicide treatments alone. These results indicate that terminating early is key in preventing cash crop yield loss.

WEED EXPOSURE TO SUBLETHAL RATES OF HERBICIDES AS A RESULT OF PESTICIDE DRIFT. Bruno Canella Vieira*1, Scott Ludwig2, Joe D. Luck3, Keenan L. Amundsen3, Todd A. Gaines4, Rodrigo Werle3, Greg R Kruger5; 1University of Nebraska, Lincoln, NE, 2Nichino America, Arp, TX, 3University of Nebraska-Lincoln, Lincoln, NE, 4Colorado State University, Fort Collins, CO, 5University of Nebraska, North Platte, NE (162)

The negative effects of herbicide-drift on sensitive vegetation have been extensively studied. Little or no information regarding the effects of herbicide drift on weeds has been reported, especially when considering that recurrent selection with sub-lethal rates of herbicides in associated with several cases of herbicide resistance. Therefore, the objective of this study was to investigate the drift deposition pattern and the herbicide injury caused by physical particle drift on Palmer amaranth (Amaranthus palmeri) and common waterhemp (Amaranthus tuberculatus var. rudis). A wind tunnel study was conducted at the Pesticide Application Technology Lab, University of Nebraska – Lincoln West Central Research and Extension Center, in North Platte, NE. Glyphosate, dicamba, and 2,4-D applications (140 L ha-1) were made using two different nozzles (AI95015EVS and TP95015EVS) at 140 kPa under a 16 km hr-1 airstream. Drift collectors (Mylar cards), Palmer amaranth, and common waterhemp plants were positioned at different downwind distances in the wind tunnel (0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 7, and 12 m from the nozzle). Drift percentage was estimated by fluorimetry as a fluorescent tracer was added to herbicide solutions. Palmer amaranth and common waterhemp biomass reduction was recorded at 21 DAT. Application droplet size spectra were evaluated using a Sympatec Helos laser diffraction instrument. The venturi nozzle reduced the percentage of drift for herbicide applications. Herbicide injury decreased as downwind distances were increased, especially when applications were performed with the venturi nozzle. Herbicide deposition caused by physical particle drift were generally similar to the sub-lethal rates reported to be associated with resistance evolution in previous recurrent selection studies, especially for applications performed with the TP nozzle producing smaller droplets and consequently more drift. Understanding and mitigating herbicide-drift exposure may represent an important strategy to delay herbicide resistance evolution in weeds.

COMMON MILKWEED INJURY DUE TO FOMESAFEN EXPOSURE AND ITS IMPACT ON MONARCH UTILIZATION. Sydney Lizotte-Hall*, Bob Hartzler; Iowa State University, Ames, IA (163)

The monarch butterfly (Danaus plexippus) population has declined over the last two decades, causing increased focus on glyphosate and its impact on common milkweed (Asclepias syriaca) presence in agricultural crop fields. Research documenting the importance of common milkweed in crop fields for monarch reproduction is lacking. The objective of this project is to determine whether non-lethal injury associated with herbicide use reduces utilization of common milkweed within crop fields by monarchs. Field experiments were conducted to investigate impacts of herbicide exposure on oviposition preference of monarchs. Common milkweed seedlings were transplanted in patches containing five plants spaced 25 cm apart in a no-till soybean field shortly after soybean planting in 2016. A 0.9 m buffer separated patches. Treatments included an untreated control and 0.14 kg ha-1 fomesafen plus 0.5% v v-1 crop oil concentrate. The experiment was repeated in the same area in 2017 by planting soybean no-till prior to common milkweed emergence. Milkweed leaves displayed chlorosis and necrotic lesions five d after application. Twelve d following application many leaves contacted by fomesafen dehisced, and plants averaged a rating of 4 (1 = healthy and 5 = dead). Plants recovered as new leaves emerged from the apical meristem, and four weeks after application plants averaged an injury rating of 2. Multiple stems emerged from the majority of plants that were established in 2016, and response to fomesafen was similar to 2016. Dry weight of common milkweed ten wk after application was not affected by fomesafen in either year. Common milkweed were examined for monarch eggs and larval instars weekly from May to August. In 2016 plots averaged 0.6 eggs, whereas in 2017 plots averaged 38.5 eggs. Fomesafen did not affect ovipositing. The increased egg densities during 2017 may be due to adult female monarchs being better able to detect the multiple and more vigorous milkweed ramets emerging from established rootstocks. Additionally, many of the second-year milkweeds produced flowers that could attract monarchs. Larval instars were observed and recorded throughout the study. Two fifth-instars were found (one treatment-1) during the duration of the study, suggesting high mortality rate in the soybean field. A greenhouse study examined milkweed response to four rates of fomesafen (0.03, 0.07, 0.14 kg ha-1 and 0.28 kg ha-1 plus 0.5% v v-1 crop oil concentrate) and three rates of additional herbicides: glufosinate (0.23, 0.47 kg ha-1 and 0.91 kg ha-1 plus 3.4 kg AMS ha-1); imazethapyr (0.04, 0.07 kg ha-1 and 0.14 kg ha-1 plus 0.014 kg AMS L-1 + 1.25% v v-1 crop oil concentrate); and mesotrione (0.05, 0.10 kg ha-1 and 0.21 kg ha-1 plus 0.96 kg AMS L-1 + 1% v v-1crop oil concentrate) when common milkweed was approximately 20 cm in height. The high rate represents 2X the typical use rate in corn or soybean. None of the herbicide rates caused plant mortality; plants showed signs of recovery two wk post application. Milkweed injury was greatest with imazethapyr > mesotrione > glufosinate based on an injury rating scale (1 = healthy and 10 = dead).

EVALUATION OF 'PLANTING GREEN': IMPACTS OF DELAYED CEREAL RYE TERMINATION ON WEED EMERGENCE AND SOYBEAN PRODUCTION. Erin C. Hill*; Michigan State University, E Lansing, MI (164)

The potential benefits of incorporating cover crops into field crop rotations are often limited by Michigan’s brief growing season. The objectives of this research were to explore the

impacts ‘planting green’ (planting a cash crop into a living cover crop, in this case soybeans planted into cereal rye), focusing on the effect of termination method and timing. Rye termination methods included a glyphosate application, mowing, and a combination of the two methods. Termination timings were based on Feeke’s stage (F) of the rye and included 6.5, 9, and 10.5. Evaluations included rye biomass and C:N ratio, soil moisture, temperature and nitrogen availability, weed emergence by species in supplemented and natural populations, and soybean emergence, development, nutrient status and yield. Rye biomass accumulation ranged from 670 to 2,300 kg ha-1, with C:N ratios from 27 to 49 depending on the termination stage and year. Mowing alone at the F9 and 10.5 stages was not effective for terminating rye, with a follow-up glyphosate application required. No differences in soil moisture or temperature were observed between the rye and no cover crop treatments. Delaying rye termination until Feeke’s 10.5 reduced soil nitrogen availability by 17 to 22 kg ha-1 compared with no cover crop (2016, 2017 still being analyzed). The presence of a rye cover crop suppressed season-long total weed emergence compared with no cover, with delayed termination leading to greater suppression in some instances. Mowing the rye (with a follow-up glyphosate application) reduced weed emergence more so than no cover crop or spraying alone. Soybean stand two wk after planting was not impacted by rye termination timing or method. Delaying rye termination until F10.5 did not affect soybean nutrient status, but slowed development and reduced soybean leaf area and yield compared to the no cover treatment. Understanding the implications and potential limitations of planting soybeans into a living cover crop will provide growers with one more tool to improve integrated weed management.

EVALUATION OF COVER CROP SENSITIVITY TO RESIDUAL SOYBEAN HERBICIDE TREATMENTS. Derek Whalen*1, Mandy Bish1, Shawn Conley2, Aaron Hager3, Jason Norsworthy4, Dan Reynolds5, Larry Steckel6, Bryan G. Young7, Kevin W Bradley1; 1University of Missouri, Columbia, MO, 2University of Wisconsin, Madison, WI, 3University of Illinois, Urbana, IL, 4University of Arkansas, Fayetteville, AR, 5Mississippi State University, Starkville, MS, 6University of Tennessee, Knoxville, TN, 7Purdue University, West Lafayette, IN (165)

In recent years, the use of cover crops has increased in mid-western crop production systems. An important aspect of successful cover crop establishment is the preceding crop and herbicide use, as some herbicides have the potential to persist in the soil for several months. Few studies have been conducted to evaluate the sensitivity of cover crops to common residual herbicides used in soybean production. An identical field experiment was conducted in 2016 in Arkansas, Illinois, Indiana, Missouri, Tennessee and Wisconsin to evaluate the potential of fomesafen, imazethapyr, chlorimuron + thifensulfuron, s-metolachlor, acetochlor, pyroxasulfone, acetochlor + fomesafen and fomesafen + s-metolachlor to carryover and injure or reduce the establishment of Austrian winter pea, cereal rye, crimson clover, hairy vetch, Italian ryegrass, oats purple top turnip, tillage radish, triticale and wheat. Each of the herbicides were applied 21 and 42 d after planting (DAP). Three additional treatments that were evaluated included sulfentrazone + s-metolachlor pre-emergence (PRE), sulfentrazone + s-metolachlor PRE followed by (fb) fomesafen + s-metolachlor 21 DAP, and sulfentrazone + s-metolachlor PRE fb fomesafen + s-metolachlor 21 DAP fb acetochlor 42 DAP. Visible estimations of injury and cover crop biomass was determined 28 d after emergence (DAE) as well as mid-March the following spring. Data were subjected to analysis using the PROC GLIMMIX procedure in SAS and means were separated using Fisher’s Protected LSD ($P \leq 0.05$). Across cover crop species, tillage radish was injured the most by the previous residual herbicide treatments in soybean. Across herbicide treatments, the sensitivity of cover crops to herbicide residues, from greatest to least, was tillage radish > oats = Italian ryegrass = purple top turnip = triticale > cereal rye = Austrian winter pea = wheat = hairy vetch > crimson clover. Fomesafen (21 and 42 DAP), sulfentrazone + s-metolachlor fb fomesafen + s-metolachlor and sulfentrazone + s-metolachlor fb fomesafen + s-metolachlor fb acetochlor resulted in 23 to 32% injury to tillage radish. Across cover crop and treatment timings, applications of pyroxasulfone, sulfentrazone + s-metolachlor fb s-metolachlor + fomesafen, and sulfentrazone + s-metolachlor fb fomesafen + s-metolachlor fb acetochlor resulted in the most injury across cover crops. Results from this study show that cover crop selection following previous residual herbicide applications is crucial for successful cover crop establishment in the fall.

MANAGING COVER CROP TERMINATION FOR CONTROL OF PALMER AMARANTH IN ROUNDUP READY XTEND SOYBEANS. Drake Copeland*1, Larry Steckel2; 1University of Tennessee, Jackson, TN, 2University of Tennessee, Knoxville, TN (166)

Palmer amaranth (Amaranthus palmeri) is the most problematic weed in row-cropping systems in the southern US. Currently, Palmer amaranth has evolved resistance to herbicides from six different modes of action. Consequently, integrated weed management tactics are needed to control Palmer amaranth. Previous researchers have documented the use of a cover crop can reduce herbicide applications and suppress summer annual weeds. Research is lacking on the role of residual herbicides used at cover crop termination to facilitate continued Palmer amaranth control. Therefore, the objective of this research was to evaluate the use of residual herbicides at different cover crop termination timings on Palmer amaranth control as well as on soybean development and yield. A study was initiated to evaluate residual herbicides and cover crop management for in-season weed control of Palmer amaranth at West Tennessee Research and Education Center in Jackson, TN. A cover crop of wheat and crimson clover was seeded at 67 kg ha-1 and 17 kg ha-1, respectively 11/14/2016. Treatments were arranged as a factorial within a randomized complete block design. Factor A consisted of termination timing at two levels and factor B was residual herbicide at seven levels. Plots were two-76-cm rows, 7.6 m in length. Termination timings included applications at planting and 14 d after planting (DAP). Termination treatments included a tank-mixture of glyphosate at 1.26 kg ae ha-1 and dicamba at 0.56 kg ae ha-1 plus a residual herbicide. Residual herbicides included s-metolachlor alone at 1.06 kg ai ha-1, micro-encapsulated acetochlor alone at 1.26 kg ai ha-1, s-metolachlor at 1.06 kg ai ha-1 plus fomesafen at 270 g ai ha-1, micro-encapsulated acetochlor at 1.26 kg ai ha-1 plus fomesafen at 270 g ai ha-1, pyroxasulfone alone at 120 g ai ha-1, pyroxasulfone at 120 g ai ha-1 plus fomesafen at 270 g ai ha-1 as well as a no residual herbicide (nontreated) check. Data were collected on visual weed control, d until 10-cm tall Palmer amaranth, Palmer amaranth density, soybean plant population and height, and soybean yield. Data were subjected to an analysis of variance with appropriate mean separation techniques at $\alpha = 0.05$. Cover crop control seven DAA was ≥ 99% for all treatments at both termination timings. No differences in soybean plant population or height were observed at 14, 28 DAP and R1 growth stage. The number of d until 10-cm tall Palmer amaranth was affected by termination timing. Regardless of residual herbicide used, terminating the cover crop 14 DAP resulted in more d until 10-cm tall Palmer amaranth (83 d) than terminating at planting (58 d). When pooled across termination timing, differences in d until 10-cm tall Palmer amaranth among residual herbicides were observed. Treatments of micro-encapsulated acetochlor (121 d) and micro-encapsulated acetochlor + fomesafen (115 d) provided more d until 10-cm tall Palmer amaranth than other treatments. Furthermore, s-metolachlor alone and the non-treated check provided the least amount of d (38 and 32 d, respectively). At R1, the effect of termination timing was significant for density of Palmer amaranth. Palmer amaranth density was greater when cover crop was terminated at planting (47,000 plants ha-1) than 14 DAP (25,000 plants ha-1). Density of Palmer amaranth at R1 was also affected by residual herbicide. Micro-encapsulated acetochlor alone (3,000) and micro-encapsulated acetochlor plus fomesafen (6,000) had less Palmer amaranth ha-1 than other residual herbicides where the non-treated check (96,000 plants ha-1) had the most. Soybean yield was not affected by termination timing or residual herbicide. On average, soybeans treated with a residual herbicide yielded 209 kg ha-1 greater than the non-treated check. Termination timing of cover crop or residual herbicide did not impact soybean plant population, height or yield. As cover crop termination was delayed, the number of d until 10-cm tall Palmer amaranth increased and Palmer amaranth densities decreased. Additionally, selection of a residual herbicide at cover crop termination is a significant factor in Palmer amaranth control. Results indicate that delaying cover crop termination to 14 DAP combined with an effective residual herbicide can be advantageous in dicamba-tolerant soybeans to reduce the number of herbicide applications and increase control of Palmer amaranth.

STRATEGIES FOR CONTROL OF WATERHEMP THAT SURVIVED A POST CONTACT HERBICIDE. Jesse A. Haarmann*, Bryan G. Young, William G. Johnson; Purdue University, West Lafayette, IN (167)

Contact herbicides can fail to adequately control weeds in a variety of situations including unfavorable application conditions, inadequate herbicide rate and coverage, or herbicide resistance. Surviving weeds are typically more branched, stressed, and more difficult to control as a result of the first application. Chemical control choices are often limited by crop herbicide tolerance, crop growth stage, and calendar date. To determine the optimum herbicide choice and timing to control waterhemp escapes, a field trial was conducted in Indiana on waterhemp in 2017. Plots were sprayed with a sub-lethal rate of glufosinate or fomesafen to simulate a field situation of herbicide failure. Sequential treatments of glufosinate at 450 and 740 g ai ha-1, fomesafen at 450 g ai ha-1, lactofen at 220 g ai ha-1, 2,4-D at 1120 g ae ha-1, and dicamba at 560 g ae ha-1 were made 3, 7, or 11 d after initial application. Waterhemp control was evaluated by counting number of new branches on marked plants at one and two wk following each sequential herbicide application and visual assessments of biomass reduction recorded one, two, and three wk after each sequential herbicide application. Timing of sequential application influenced control for four of six sequential herbicide treatments. Glufosinate at both rates had 9 to 11% greater control when sequential treatment was applied 11 d after initial application compared to 3 d after initial application. Dicamba and 2,4-D had 55 to 100% fewer branches when sequential treatment was applied three d after the initial application compared to 11 d after initial application. Sequential herbicide treatments of glufosinate and fomesafen at all timings and 2,4-D at the three d timing had the greatest control. Across all sequential application timings, glufosinate and fomesafen had greater control than 2,4-D which was greater than lactofen and dicamba.

WEED CONTROL AND CROP SAFETY IN BOLT SOYBEAN. Zahoor A. Ganie*1, Amit J. Jhala2; 1University of Nebraska-Lincoln, USA, Lincoln, NE, 2University of Nebraska-Lincoln, Lincoln, NE (168)

Soybean varieties with increased tolerance for acetolactate synthase (ALS) inhibitors (Bolt soybean) will provide more flexibility to use ALS inhibitors and a zero-d plant-back opportunity after application of ALS herbicides in a preceding crop or preplant treatments. A field study was conducted at the South Central Agricultural Laboratory, Clay Center, NE in 2016 and 2017 using a randomized complete block design with four replications. The objective of this study was to evaluate the herbicide programs including ALS inhibitors for weed control and crop safety in Bolt soybean. Results indicated that herbicide-mixtures with multiple sites of action including rimsulfuron + thifensulfuron tank-mixed with flumioxazin, flumioxazin + chlorimuron, pyroxasulfone, chlorimuron + metribuzin, or saflufenacil + imazethapyr + dimethenamid-P provided 99% weed control compared to rimsulfuron (70 to 81%), thifensulfuron (49 to 67%) and rimsulfuron + thifensulfuron (< 92%) at 21 DAPRE. At 30 d after POST, PRE followed by (fb) POST programs involving multiple herbicide sites of action provided 75 to 92% waterhemp (Amaranthus rudis) control, and 82 to 98% control of velvetleaf (Abutilon theophrasti), common lambsquarters (Chenopodium album) and grass weeds compared to exclusive application of ALS inhibitors alone as PRE, POST or PRE fb POST. Weed Biomass reduction and density were in conformity with the control. Non-treated control resulted in the lowest yield of 2,809 kg ha–1 compared with 3,406 to 4,611 kg ha–1 under the herbicide programs without differences among them. Soybean injury was transient and varied from 3 to 8% at 21 d after PRE, and POST treatments without causing any yield losses. ALS-tolerant soybean was developed through traditional breeding and is available in glyphosate-resistant soybean cultivars to provide an opportunity to use ALS inhibitors along with other herbicide groups for the control of resistant weeds, and to prevent soybean injury due to ALS herbicides used in previous crops such as wheat.

METHODS TO CONTROL RAGWEED POPULATIONS FOLLOWING SURVIVAL OF A POST HERBICIDE TREATMENT. Wyatt S. Petersen*, Jesse A. Haarmann, Bryan G. Young, William G. Johnson; Purdue University, West Lafayette, IN (169)

Failed herbicide performance can result from multiple factors, including environmental factors, such as unexpected precipitation or varying degrees of sunlight, herbicide resistance, or applicator error. Failed applications lead to weed escapes, which allow weeds to regrow, compete with crops later in the season, and contribute to the soil seed bank. Weed escapes can also reduce yield and contribute to herbicide resistance over time. To control weed escapes, a second herbicide application is routinely used to control weed regrowth. The efficacy of different herbicides on giant ragweed after survival of the initial herbicide application is not well known. To simulate a failed herbicide application, 3 x 9 m plots of giant ragweed were sprayed with a low rate (280 g ha-1) of fomesafen, followed by treatments of herbicides 3, 6, and 11 d after initial application. Five 30-cm tall giant ragweed plants were selected from each plot. The herbicides used as follow up treatments were 1120 g ha-1 2,4-D, 220 g ha-1 lactofen, 560 g ha-1 dicamba, 450 g ha-1 fomesafen, 450 g ha-1 glufosinate, and 760 g ha-1 glufosinate. Height, visually-estimated control, and number of branches were measured 7, 14 and 21 d after the sequential application. Biomass of the selected plants was collected 14 DAT and dry weight was measured. Glufosinate and fomesafen showed the best control and fewest branches when applied 11 DAT, while the synthetic auxins dicamba and 2,4-D exhibited the best control and lowest branch number when applied three d after the first application. Low rate and high rate glufosinate were equally effective when applied 11 DAT, but low rate glufosinate was unable to adequately control giant ragweed when applied three DAT. Lactofen was the least effective in control and branch number overall, but was more effective when applied 11 DAT. Lactofen and low rate glufosinate were the most variable across treatment timings.

EFFICACY OF HALAUXIFEN-METHYL BASED HERBICIDE PROGRAMS FOR MANAGEMENT OF GLYPHOSATE-RESISTANT HORSEWEED IN SOYBEAN AND EVALUATION OF PREPLANT INTERVALS FOR CROP SAFETY. Marcelo Zimmer*1, Bryan G. Young1, Bill Johnson2; 1Purdue University, West Lafayette, IN, 2Purdue University, W Lafayette, IN (170)

The evolution of glyphosate-resistant (GR) weeds such as horseweed is a major challenge in no-till soybean production systems. Effective GR horseweed control with preplant burndown applications is necessary to prevent potential soybean yield losses due to competition and manage the soil weed seedbank. Often, preplant burndown applications to control GR horseweed utilize synthetic auxin herbicides. 2,4-D and dicamba must be applied at least 14 d before planting because soybean phytotoxicity can occur under certain environmental conditions. Halauxifen-methyl is a new synthetic auxin herbicide for control of broadleaf weeds in preplant burndown applications in soybean, cotton, and corn at low use rates (5 g ae ha-1). Field experiments were conducted to evaluate the efficacy of herbicide programs containing halauxifen-methyl for GR horseweed control in comparison to existing herbicide programs utilized in no-till GR soybean systems. Additionally, field experiments were conducted to evaluate the potential of halauxifen-methyl to cause soybean phytotoxicity when applied at five different preplant intervals at 5 g ae ha-1. Herbicide treatments that included halauxifen-methyl, dicamba, and saflufenacil controlled GR horseweed (87 to 97% control), while treatments containing glufosinate and 2,4-D, as well as glyphosate alone, resulted in less control (33 to 82% control) at 35 d after treatment (DAT). In 2015, soybean phytotoxicity from halauxifen-methyl did not occur in the plant-back study for any of the preplant intervals at any of the sites. In 2016, soybean phytotoxicity from halauxifen-methyl was observed at 14 d after planting (DAP) for treatments applied at 14 d before planting (DBP), 7 DBP, and 0 DBP at different sites, ranging from 1 to 15%. Soybean phytotoxicity affected unifoliate leaves only, while the first trifoliate did not show any phytotoxicity at 21 DAP. These results indicate that herbicide programs containing halauxifen-methyl control GR horseweed, although soybean phytotoxicity can occur if applied too close to planting. Soybean plants can quickly overcome phytotoxicity and preplant application timings of halauxifen-methyl did not affect soybean stand counts or grain yield at any site or year.

MANAGING GLYPHOSATE-RESISTANT HORSEWEED AND SUMMER ANNUALS IN NO-TILL ENLIST SOYBEANS. Connor L. Hodgskiss*1, Mark Loux2, William G. Johnson3; 1Purdue University, Lafayette, IN, 2Ohio State University, Columbus, OH, 3Purdue University, West Lafayette, IN (171)

To combat growing herbicide resistant weed populations, Dow AgroSciences developed soybean (Glycine max) varieties that are resistant to 2,4-D. An effective POST herbicide on problematic species such as horseweed (Conyza canadensis), giant ragweed (Ambrosia trifida), and tall waterhemp (Amaranthus tuberculatus) which will allow for a more diverse herbicide program in soybean production. The objective of this research was to evaluate preplant programs followed by POST applications to control glyphosate-resistant horseweed and other summer annual species in Indiana and Ohio. The Indiana location contained horseweed and tall waterhemp, while the Ohio location contained horseweed and giant ragweed. Four different preplant herbicide programs were used to evaluate control of horseweed. The four preplant programs were centered around glyphosate (1.1 kg ae ha-1) + 2,4-D choline (1.1 kg ae ha-1), paraquat (1.1 kg ai ha-1), saflufenacil (10 g ai ha-1) + imazethapyr (29 g ai ha-1) + pyroxasulfone (50 g ai ha-1), and glufosinate (0.60 kg ai ha-1), and each was compared with the addition of metribuzin (0.32 kg ai ha-1), with the exception of the saflufenacil + imazethapyr + pyroxasulfone. Preplant programs were followed by POST herbicide programs for control of horseweed, waterhemp, and giant ragweed. The POST herbicide treatments consisted of glyphosate (1.1 kg ae ha-1), glyphosate + fomesafen (0.33 or 0.40 kg ai ha-1), glyphosate + 2,4-D choline(1.1 kg ae ha-1) , glufosinate (0.60 kg ai ha-1), and glufosinate + 2,4-D choline. At 14 DAT glyphosate + 2,4-D choline showed the least amount of control when compared with the other preplant treatments with control being 72% with the addition of metribuzin and 57% without metribuzin. Other preplant programs ranged from 82-100% for control of horseweed at the Ohio location, while all treatments had at least 85% control at the Indiana location. The Indiana location was less variable and treatments which included 2,4-D choline and cloransulam (26 g ai ha-1) + sulfentrazone (0.20 kg ai ha-1) provided 12% greater control of horseweed than pyroxasulfone + safluenacil + imazethapyr + metribuzin. When these preplant programs were followed by a POST applicaition of glyphosate + 2,4-D choline horseweed control was 100% at the Ohio location. Tall waterhemp was controlled 91-96% when POST treatments of glyphosate or glufosinate included 2,4-D choline regardless of the preplant program. In order to obtain giant ragweed control greater than 84% an additional POST application would be needed at the Ohio location.

MAKING METRIBUZIN BETTER WITH A NEW FORMULATION. Gregory K. Dahl*1, Ryan J. Edwards2, Thomas A. Hayden3, Jo A. Gillilan4, Danny M. Brown1, Eric Spandl5, Joe V. Gednalske1, Raymond L. Pigati6; 1Winfield United, River Falls, WI, 2WinField United, River Falls, WI, 3Winfield United, Owensboro, KY, 4Winfield United, Springfield, TN, 5Winfield Solutions LLC, Shoreview, MN, 6WinField United, Shoreview, MN (172)

Metribuzin has a long history of weed control in the US. Introduced in 1973, metribuzin was initially widely used in many crops. The use of metribuzin decreased with the introduction of bentazon, PPO-inhibiting herbicides, ALS-inhibiting herbicides and then the introduction of glyphosate-tolerant soybeans. The evolution of herbicide-resistant weeds has caused a large increase in the interest and use of metribuzin in weed control programs. Metribuzin can be made into dry or liquid formulations. Older liquid formulations of metribuzin had many issues (i.e. short storage shelf life, mixing/compatibility difficulties and handling problems including difficulty getting the product out of containers and screen plugging). Much of the industry switched to less expensive dry formulations over time even though dry metribuzin formulations need ample time and water to disperse adequately. Applicators desired a liquid metribuzin formulation that did not have the storage and handling issues of the older liquid formulations. Dimetric® Liquid (AGH15003) is a liquid formulation of metribuzin that is easier to mix and apply than dry formulations. Dimetric® Liquid contains 33% metribuzin active ingredient (0.36 kg L-1 or 3 lb gallon-1). Labeled use rates of Dimetric® Liquid are based on the same amount of active ingredient as that of dry metribuzin products. Dimetric® Liquid formulation has longer shelf life and easier mixing with less handling and compatibility issues than older liquid metribuzin formulations. Weed control with Dimetric® Liquid was greater than or equal to that of other metribuzin formulations when compared at equal amounts of active ingredient.

COMPARISON OF HORSEWEED CONTROL IN GLYPHOSATE-, GLUFOSINATE-, AND DICAMBA-RESISTANT SOYBEAN IN KENTUCKY. Zachary K. Perry*1, Travis Legleiter2, Nick Fleitz1, J D Green1; 1University of Kentucky, Lexington, KY, 2University of Kentucky, Princeton, KY (173)

Glyphosate- and ALS-resistant horseweed is present in Kentucky generating a need for research evaluating control of herbicide-resistant horseweed in soybean. Field experiments were conducted in a randomized complete block design with four replications at two locations in Kentucky. Herbicide programs to target horseweed consisting of a preplant foliar (PPF) burndown application followed by a post-emergence (POST) treatment were evaluated on three different soybean traits: glyphosate resistant, glyphosate and dicamba resistant, and glufosinate resistant. Herbicide treatments were applied with a three m boom at a spray volume of 140 L ha-1 with a CO2 propelled backpack or an ATV sprayer. Herbicide programs in the glyphosate-resistant soybean that contained chlorimuron, cloransulam, or saflufenacil applied as a PPF burndown resulted in 89% or greater control at the Princeton location. Whereas at the Versailles location only those treatments containing saflufenacil resulted in 90% or greater control, indicating possible ALS-resistance at this site. Glufosinate-resistant programs that involved glufosinate applied PPF and/or POST showed greater than 90% control. Treatments that received a PPF or POST application of dicamba had greater than 80% control of horseweed. Herbicide programs that incorporated dicamba or glufosinate in the PPF burndown application or POST provided effective control and would be recommended to help control horseweed in soybean varieties containing traits tolerant to these herbicides. Programs that rely only on glyphosate as a PPF treatment and POST application did not provide effective horseweed control. The inclusion of saflufenacil in the PPF burndown was the only consistently effective horseweed control program in the glyphosate-resistant soybean system.

SURVEY OF PALMER AMARANTH FOR RESISTANCE TO FOMESAFEN, DICAMBA, AND GLUFOSINATE IN MISSISSIPPI AND ARKANSAS. Paul Feng*1, Chenxi Wu2, Alejandro Perez-Jones1; 1Monsanto Company, Chesterfield, MO, 2Monsanto Company, St Louis, MO (174)

Glyphosate resistance (GR) has become prevalent in Palmer amaranth. Increased use of PPO herbicides to control GR-Palmer amaranth has led to selection of PPO resistance. Glufosinate is increasingly used in soybean and cotton to control GR-Palmer amaranth and under selection pressure for resistance. Dicamba is a new tool for Palmer amaranth control. Dicamba-tolerant soybean and cotton were planted in >1 million hectares in 2017 increasing selection pressure for dicamba resistance. The purpose of this survey is to establish a base-line for efficacies of fomesafen, dicamba and glufosinate in Palmer amaranth. About 150 seed samples were randomly collected along the Mississippi river in the states of Mississippi and Arkansas in 2016-17. This presentation will summarize our greenhouse studies on the performance of dicamba, glufosinate and fomesafen in populations of Palmer amaranth.

DICAMBA AND 2,4-D EFFICACY ON PALMER AMARANTH AND COMMON WATERHEMP. Nathaniel R. Thompson*, Dallas E. Peterson; Kansas State University, Manhattan, KS (175)

Auxinic herbicides have been widely used for broadleaf weed control since the mid 1940's. With new auxinic-herbicide-resistant traits in corn and soybean, use of these herbicides is likely to increase. Glyphosate-resistant Palmer amaranth and common waterhemp are two primary weed problems that will be targeted with dicamba and 2,4-D in the new systems. Both herbicides control the Amaranthus spp, but there are few direct comparisons of the two herbicides for control. Four site years of field research were conducted in 2017 near Manhattan and Ottawa KS, to evaluate dicamba and 2,4-D postemergence efficacy on Palmer amaranth and common waterhemp. The experiment was a randomized complete block design with five rates of dicamba (140, 280, 560, 1121, and 2242 g ae ha-1) and 2,4-D (140, 280, 560, 1121, and 2242 g ae ha-1) to evaluate efficacy of the Amaranthus spp. Two experiments were conducted near Manhattan with a natural population of Palmer amaranth (>50 plants m-2) and two experiments near Ottawa with a natural population of common waterhemp (>60 plants m-2). Treatments were applied to weeds less than 10-cm tall with a backpack sprayer calibrated to deliver 140 L ha-1 with the recommended spray nozzles for each herbicide. Dicamba provided better Palmer amaranth and common waterhemp control than 2,4-D across the rates evaluated. Control of Palmer amaranth was 94% and 99% with dicamba rates of 1121 and 2242 g ae h-1, respectively, while 2,4-D never provided more than 80% control at any rate. The highest rates of both dicamba and 2,4-D provided greater than 90% common waterhemp control, but control was less than 79% with lower rates of both herbicides. Palmer amaranth and common waterhemp control did not exceed 73% with the highest labelled postemergence rates of either dicamba or 2,4-D. Efficacy may have been reduced in this research because of the high populations and coverage issues. Dicamba and 2,4-D need to be part of an integrated weed management program in traited soybean to achieve acceptable Amaranthus spp control and minimize the potential for evolving herbicide resistance.

COMPARISON OF SOIL-APPLIED AND POSTEMERGENCE HERBICIDE PROGRAMS ON TWO POPULATIONS OF HERBICIDE-RESISTANT PALMER AMARANTH. Nick Fleitz*1, J D Green1, Patrick Tranel2; 1University of Kentucky, Lexington, KY, 2University of Illinois, Urbana, IL (176)

With the introduction of herbicide-resistant Palmer amaranth into Kentucky during the past 10 yr there has been an increasing concern for effective control measures in grain production. Currently more than half the 120 counties in Kentucky contain populations of Palmer amaranth. Field trials conducted in 2017 on two experiment sites employed a factorial experimental design containing five pre-emergent (PRE) herbicide treatments, including sulfentrazone + s-metolachlor(196 + 1,771 g aiha-1), s-metolachlor + metribuzin (2206 + 526 g ai ha-1), flumioxazin + pyroxasulfone + chlorimuron (77 + 99 + 21 g ai ha-1), s-metolachlor + metribuzin + fomesafen (2128 + 470 + 426 g ai ha-1) and flumioxazin + chlorimuron + metribuzin (81 + 25 + 280 g ai ha-1). PRE treatments were followed by one of five foliar applied postemergence herbicide treatments consisting of glufosinate (650 g ai ha-1) with and without acetochlor (1817 g ai ha-1), dicamba + glyphosate(560 + 1120 g ai ha-1), glyphosate + 2,4-D (1130 + 1020 g ai ha-1), fomesafen + s-metolachlor (370 + 1670) and no foliar POST herbicide application. Visual estimations of control, plant density counts and biomass samples were collected to determine treatment efficacy. Pre-emergent treatments containing flumioxazin + pyroxasulfone + chlorimuron or s-metolachlor + metribuzin + fomesafen were the most effective, averaging >90% suppression of Palmer amaranth thirty d after application. PRE treatments consisting of sulfentrazone + s-metolachlor provided the least effective suppression of Palmer amaranth thirty and forty d after application. POST treatments containing glyphosate + dicamba or glyphosate + 2,4-D following a PRE treatment achieved the most effective control of Palmer amaranth. Plant density counts reflect the control rating data. PRE treatments consisting of three-way mixtures of flumioxazin + pyroxasulfone + chlorimuron or s-metolachlor + metribuzin + fomesafen followed by a POST herbicide treatment provided the greatest Palmer amaranth control.

COMPARISONS OF SOYBEAN TRAITS AND HERBICIDE PROGRAMS FOR THE CONTROL OF MULTIPLE-RESISTANT WATERHEMP AND OTHER COMMON WEED SPECIES. Eric Oseland*1, Mandy Bish2, Kevin W Bradley2; 1University of Missouri, Columbia, IL, 2University of Missouri, Columbia, MO (177)

New commercially available herbicide tolerant soybean varieties have provided growers with new choices for weed management that were not previously available. The objective of this research was to compare weed management and yield across a variety of different herbicide-resistant soybean systems. Separate field trials were conducted in 2017 in Columbia and Renick, Missouri. The traits evaluated included glyphosate-resistant, glyphosate- and dicamba-resistant, glufosinate-resistant, and glufosinate-, glyphosate- and 2,4-D-resistant soybean, which was evaluated as a glyphosate plus 2,4-D and a glufosinate plus 2,4-D system. Two primary weed management strategies were evaluated in each soybean system: 1) a pre-emergence (PRE) application of 0.2 kg ha-1 sulfentrazone plus 0.03 kg ha-1 cloransulam followed by a post-emergence (POST) herbicide application appropriate for the system (PRE fb POST); and 2) the same PRE herbicide followed by the appropriate POST herbicide plus 1.1 kg ha-1 s-metolachor (PRE fb POST with residual). A conventional herbicide system consisting of the same PRE herbicide followed by 0.21 kg ha-1 lactofen plus 0.14 kg ha-1 clethodim plus 1.1 kg ha-1 s-metolachlor POST was also applied across soybean systems for comparison of yields. Treatments were arranged in a randomized complete block design with four replications. Visual weed control was assessed at regular intervals after treatment and weed density was determined 56 d after application (DAA). Data were analyzed using the PROC GLIMMIX procedure in SAS and means were separated using Fisher's protected LSD ($P < 0.05$). Weed control results were different between locations due to a dense population of multiple-herbicide-resistant waterhemp at the Renick site. Waterhemp was controlled 13% by glyphosate and lactofen at Renick at 56 DAA. The dicamba- and 2,4-D-resistant soybean systems exhibited greater than 90% control of broadleaf weeds at both locations with the PRE fb POST and PRE fb POST with residual weed management strategies 56 DAA. At Columbia, both herbicide treatments that included glufosinate resulted in less grass control compared to other herbicide treatments. When herbicide treatments were combined across each soybean system, soybean yields at the Columbia location were highest in the glyphosate- and dicamba-resistant and glyphosate- resistant soybeans systems. Soybean yield at the Renick location was highest with the glyphosate- and dicamba-resistant, glyphosate- and 2,4-D-resistant, and glufosinate-resistant soybean systems. Soybean yields and weed control at both locations did not benefit from the addition of a residual in the POST herbicide application. The results from this experiment will provide soybean producers with valuable information regarding weed management and soybean system selection.

BICYCLOPYRONE AS PART OF AN INTEGRATED WEED MANAGEMENT PROGRAM IN VEGETABLE CROPS. Colin J. Phillippo*1, Bernard H Zandstra2; 1Michigan State University, East Lansing, MI, 2Michigan State University, E Lansing, MI (178)

Bicyclopyrone is a new HPPD-inhibitor herbicide developed for use in corn (Zea mays). It is currently marketed as a pre-mixture with mesotrione, atrazine, and s-metolachlor for corn. Bicyclopyrone was evaluated over five years for its crop safety and weed control efficacy in multiple vegetable crops throughout Michigan. Bicyclopyrone was applied preemergence to asparagus (Asparagus officinalis) at 0.05 kg ha-1 alone and tank-mixed with diuron and clomazone, which caused no yield reduction. In cucumber (Cucumis sativus), bicyclopyrone applied preemergence at 0.037 and 0.05 kg ha-1 with ethalfluralin and clomazone caused no crop injury. Bicyclopyrone applied postemergence at 0.037 kg ha-1 caused 15% yield reduction and resulted in fewer large fruit. Bicyclopyrone was safe on buttercup squash (Cucurbita maxima), butternut squash (Cucurbita moschata), and Howden pumpkin (Cucurbita pepo) at 0.037 kg ha-1, and marginally safe at 0.05 kg ha-1. Bicyclopyrone was safe preemergence on onion (Allium cepa) on muck soil up to 0.1 kg ha-1. Yields were higher if the preemergence application was delayed until 12 d after seeding. Postemergence use on onions on muck soil was safe when applied once, but repeated applications caused crop injury. Bicyclopyrone was safe on onions on mineral soil preemergence and postemergence at 0.018 kg ha-1, but reduced yields at 0.037 kg ha-1. Bicyclopyrone is also safe for use preemergence on carrot (Daucus carota subsp. Sativus) on muck soil, cilantro (Coriandrum sativum), established chives (Allium schoenoprasum), and leek (Allium ampeloprasum) and postemergence on broccoli (Brassica oleracea), cabbage, carrot on muck soil, sweet corn, and established chives. It caused crop injury when applied preemergence on broccoli, cabbage, carrot on mineral soil, celery (Apium graveolens), fennel (Foeniculum vulgare), parsley (Petroselinum crispum), and green onion, and postemergence on carrot on mineral soil, celery, and green onion. Bicyclopyrone will likely be marketed for standalone use in sufficiently tolerant vegetable crops. This product will be most useful when tank-mixed with other herbicides for broad-spectrum weed control. In asparagus, the most common herbicides used are diuron, pendimethalin, sulfentrazone, and halosulfuron. Bicyclopyrone could be tank-mixed with one or more of these herbicides to improve control of annual grasses, common ragweed (Ambrosia artemisiifolia), eastern black nightshade (Solanum ptycanthum), and pigweeds (Amaranthus spp.). In cucumber, the most common herbicides used are ethalfluralin, clomazone, halosulfuron, sethoxydim, and clethodim. Pumpkin and winter squash weed control programs typically include the same herbicides as in cucumber, with the addition of s-metolachlor and fomesafen. Adding bicyclopyrone to a cucumber or pumpkin and squash weed control program would improve control of common purslane (Portulaca oleracea), common ragweed, eastern black nightshade, redroot pigweed (Amaranthus retroflexus), and ladysthumb (Polygonum persicaria). In onions, most growers use pendimethalin, oxyfluorfen, flumioxazin, s-metolachlor, and dimethenamid-P. Including bicyclopyrone in tank-mixtures would improve control of common lambsquarters (Chenopodium album), common purslane, common ragweed, eastern black nightshade, and ladysthumb. In tolerant crops, bicyclopyrone could be used to control hairy vetch (Vicia villosa), for which there are few herbicide options available.

DELAYED CULTIVATION TO SUPPLEMENT CHLOROACETAMIDE HERBICIDES IN SUGARBEET. Nathan H. Haugrud*, Thomas J. Peters; North Dakota State University, Fargo, ND (179)

The increased prevalence of glyphosate-resistant weeds in the upper Midwest has made weed management increasing difficult for sugarbeet producers. Glyphosate-resistant weeds, particularly waterhemp (Amaranthus tuberculatus), has become an important production challenge affecting sugarbeet production in eastern North Dakota and Minnesota and has left producers with limited post emergence weed control options. The use of soil residual herbicides, particularly from the chloroacetamide family (SOA 15), has dramatically increased in response. From 2014 to 2017, use of chloroacetamide herbicides applied early postemergence has increased from

15% to 70% according to surveyed producers. Chloroacetamides are soil-applied and provide residual control of emerging weeds. Inter-row cultivation has also been used by producers in efforts to manage weeds that escape herbicide application. There is a lack of published research on the use of cultivation in a sugar beet system using chloroacetamide herbicides applied early postemergence and producers have concerns about effects of cultivation on chloroacetamide efficacy after the herbicide has been activated in soil solution. Field experiments were conducted at four locations in ND and MN in 2017 to evaluate the effect of cultivation on chloroacetamide activity and weed escapes. Information from sites near Wheaton, MN and Renville, MN are reported. Waterhemp was the primary weed at Renville and common lambsquarters (Chenopodium album) at Wheaton. Herbicides were applied to sugarbeet at the four-leaf stage and cultivation followed approximately two to three wk later. Visual estimations of control (VC) and percent visual estimation of new emergence (VENE) were evaluated before cultivation and 14, 28, and 42 d after cultivation. The number of waterhemp plants per plot was also estimated at Renville. Cultivated treatments with chloroacetamides 28 d after application gave better percent VC and percent VENE across locations as compared with non-cultivated treatments. Acetochlor, s-metolachlor, and dimethenamid-P followed by cultivation gave 95%, 98%, and 99% VENE, respectively, across locations 28 d after treatment. Non-cultivated plots with the same herbicide gave 83%, 84%, and 90% VENEC, respectively. Average number of waterhemp plants per plot 42 d after spraying was 9 and 21 in the cultivated and non-cultivated plots, respectively. At Renville, VC 28 d after applying acetochlor, s-metolachlor, and dimethenamid-P was 88%, 78%, and 91%, respectively, for cultivated plots and 73%, 62%, and 75% for non-cultivated plots.

ETHOFUMESATE APPLIED POSTEMERGENCE IN SUGARBEET: REPURPOSING A 1960S HERBICIDE. Thomas J. Peters*1, Alexa L. Lystad1, Christy L. Sprague2; 1North Dakota State University, Fargo, ND, 2Michigan State University, East Lansing, MI (180)

Ethofumesate is a time-proven herbicide for grass and small-seeded broadleaf weed control in sugarbeet. Field research from Kansas and Colorado in 1970 indicated ‘NC-8438’ (ethofumesate) provided greater than 90% green foxtail (Setaria viridis), foxtail millet (Setaria italica) and barnyardgrass (Echinochola crus-galli) control and near 90% redroot pigweed (Amaranthus retroflexus) control. Ethofumesate is soil-applied at field use rates ranging from 1.25 to 4.2 kg ai ha-1 or applied postemergence at 0.42 kg ai ha-1. Ethofumesate is absorbed by emerging shoots and roots and is translocated to the shoots where it is believed to interfere with lipid biosynthesis. Ethofumesate is sold in the US using the trade names ‘Nortron’ by Bayer CropScience, ‘Ethotron SC’ by UPI, and ‘Ethofumesate 4SC’ by Willowood USA. Willowood USA in collaboration with the Beet Sugar Development Foundation is developing a new label to expand Ethofumesate 4SC postemergence use rates from 0.42 to 4.2 kg ai ha-1 to sugarbeet having greater than two true leaves. Ethofumesate applied in combination with glyphosate may provide a second mode of action, especially for difficult to control broadleaf weeds in sugarbeet including common lambsquarters (Chenopodium album), kochia (Kochia scoparia), waterhemp (Amaranthus tuberculatus), and common ragweed (Ambrosia artemisiifolia). Little is known about postemergence broadleaf weed control from ethofumesate, especially at rates greater than 0.42 kg ha-1. Experiments were conducted at multiple field locations to evaluate broadleaf control from repeat applications (two) of glyphosate at 1.1 kg ha-1, ethofumesate at 0.21, 0.42, 0.63, 0.84, 1.12, and 2.24 kg ha-1 and glyphosate at 1.1 kg ha-1 plus ethofumesate at 0.21, 0.42, 0.63, 0.84, 1.12, and 2.24 kg ha-1. Assessment was visual 10 to 21 d after the second application by noting growth reduction or control. Sugarbeet injury across ethofumesate rates was negligible at most locations. Exception was Moorhead, MN where ethofumesate alone at 1.12 or 2.24 kg ha-1 and in combination with glyphosate at 1.1 kg ha-1 caused between 16 and 30% sugarbeet growth reduction based on visual estimations. Eleven of 16 plot evaluation-d combinations at Moorhead exhibited greater than 30% sugarbeet injury from ethofumesate alone or with glyphosate at 2.24 kg ha-1. Injury may have been confounded by 2,4-D application in a neighboring field as ethofumesate has been reported to decrease epicuticular waxes. Ethofumesate across rates provided common lambsquarters control ranging from 15 to 78% and redroot pigweed control ranging from 15 to 75%. Waterhemp control was 95 to 100%. Waterhemp germinates and emerges later than lambsquarters or redroot pigweed, usually in mid-May in North Dakota and Minnesota. Future experiments are planned to continue waterhemp evaluation using a systems approach including soil-applied and postemergence ethofumesate.

RESPONSE OF SUGARBEET TO LOW-DOSE TANK-CONTAMINATION WITH DICAMBA AND 2,4-D. Michael A. Probst*, Christy L. Sprague; Michigan State University, East Lansing, MI (181)

The development of soybean resistant to 2,4-D and dicamba will likely result in the increased use of these herbicides, considering their effectiveness for control of numerous problematic weeds. This increased use will also result in the greater potential for tank contamination with both of these herbicides, which then can be unintentionally applied to sensitive crops. This is of great concern for Michigan sugarbeet producers, as sugarbeet is extremely sensitive to both dicamba and 2,4-D. In order to gain a better understanding of the effects that these herbicides can have on sugarbeet as a result of tank contamination, studies were conducted in 2016 and 2017 in Michigan. Simulated tank-contamination applications were made using both dicamba and 2,4-D at the Michigan State University Agronomy Farm in East Lansing, MI, and at the Saginaw Valley Research and Extension Center in Richville, MI. Five herbicide rates were applied, ranging from 0.125-2% of the field use rates of both herbicides, assuming a field use rate of 1.1 kg ha-1. Treatments were applied to 2-, 6-, and 14-leaf sugarbeets. Each application timing also included a control treatment consisting of only glyphosate, and each treatment contained a full rate of glyphosate plus AMS to more accurately simulate tank contamination. Injury was evaluated for three wk following each application and again at harvest. Yield, percent sugar, and recoverable white sucrose were measured at harvest. Sugarbeet injury from 2,4-D and dicamba was greatest 14 d after treatment. Rates as low as 0.25% of 2,4-D and 0.5% of dicamba caused 10% injury. Regardless of application timing, sugarbeet injury ranged from 34-40% and 34-43% from a 2% rate of 2,4-D and dicamba, respectively. Averaged across application timings, the 2% rates of both 2,4-D and dicamba reduced sugarbeet yields. This was also reflected in recoverable white sucrose ha-1. Averaged over rates, yield was reduced by 2,4-D at the 14-leaf timing at both locations, and recoverable white sucrose was only affected at this timing in Richville. Neither application rate nor timing of dicamba impacted yield or recoverable white sucrose at East Lansing. Tank-contamination rates would generally range between 0.021% and 0.63% of what is applied in the field. Even though 2,4-D and dicamba did not reduce yield at these rates, foliar damage was apparent at 0.125% and higher. This damage may result in the presence of 2,4-D or dicamba residues in the crop that would lead to rejection of harvested sugarbeets. We are currently analyzing for the presence of 2,4-D and dicamba residues in the roots of harvested beets.

INVESTIGATIONS OF THE SENSITIVITY OF VARIOUS TREE AND ORNAMENTAL SPECIES TO DRIFTABLE FRACTIONS OF 2,4-D AND DICAMBA. Brian R. Dintelmann*, Gatlin E. Bunton, Michele Warmund, Mandy Bish, Kevin W Bradley; University of Missouri, Columbia, MO (182)

The development and implementation of 2,4-D- and dicamba-resistant soybean and cotton has been driven by the increasing spread of herbicide-resistant weed species. Off-target movement of 2,4-D and dicamba are a major concern, especially for neighbors with sensitive crop or plant species. A study was conducted in 2017 to determine the sensitivity of driftable fractions of 2,4-D and dicamba with or without glyphosate on common ornamental, shade, fruit, and nut trees, and berry species. Three driftable fractions corresponding to 1/2, 1/20 and 1/200 of the manufacture's full labeled rate (1X rate) of 2,4-D choline, 2,4-D choline plus glyphosate, dicamba, and dicamba plus glyphosate were applied to apple, crabapple, dogwood, elderberry, elm, grape, hydrangea, maple, oak, peach, pecan, redbud, rose, raspberry, strawberry, sweetgum, viburnum, and black walnut plants that were contained in 10 to 20 L pots. The experimental design was arranged as a split plot with five replications. Main plots consisted of plant species, while the subplots consisted of the herbicide treatments. Data were analyzed using the PROC GLIMMIX procedure in SAS, and means were separated using Fisher's Protected LSD. There was a overall species by treatment by rate interaction. The 1/2X rates of all four herbicide treatments caused the greatest injury across species tested 28 d after treatment (DAT). When averaged across species evaluated, the 1/2X rate of 2,4-D choline plus glyphosate resulted in 57% injury 28 DAT, while the 1/2X rate of dicamba plus glyphosate resulted in 45% injury. There were substantial differences between species in sensitivity to 2,4-D or dicamba. Based on the 1/20X rate of 2,4-D choline and dicamba alone, apple, elderberry, maple, peach, redbud, and viburnum were more sensitive to dicamba than 2,4-D; rose and black walnut were more sensitive to 2,4-D than dicamba; and there were no differences in the sensitivity of crabapple, dogwood, elm, grape, hydrangea, oak, pecan, raspberry, strawberry and sweetgum to either herbicide at the 1/20X rate. The addition of glyphosate to the 1/20X rate of dicamba increased the degree of injury of elderberry and maple compared to the 1/20X rate of dicamba alone, while the addition of glyphosate to the 1/20X rate of 2,4-D choline increased the degree of injury to apple, dogwood, and grape compared to the 1/20X rate of 2,4-D choline alone. Results from this experiment indicate that there can be substantial injury to common ornamental, shade, fruit, and nut trees, and berry species, and that there are differences in the sensitivity of most of these species to 2,4-D and dicamba.

SENSITIVITY OF TWO CLASSES OF DRY EDIBLE BEANS TO PLANT GROWTH REGULATOR HERBICIDES. Scott R. Bales*, Christy L. Sprague; Michigan State University, East Lansing, MI (183)

The increasing occurrence of herbicide-resistant weeds coupled with the recent registrations of dicamba-resistant and 2,4-D-resistant soybean will lead to the increased use of the plant growth regulator (PGR) herbicides, dicamba and 2,4-D, in Michigan. Several broadleaf crops are extremely sensitive to these herbicides, raising concerns about the implications of off-target applications. Dry edible beans are one of these sensitive crops that are of economic importance to Michigan farmers. In 2017, field trials were conducted in East Lansing and Richville, MI to investigate the effects of off-target applications of dicamba and 2,4-D on two classes of dry edible beans. The objective of this research was to gain a better understanding of how dry edible bean respond to different levels of sub-lethal exposure of the PGR herbicides at two different dry bean stages. 'Zenith' black bean and 'Merlin' navy bean were exposed to dicamba and the 2,4-D choline at the V2-V3 and preflower (V8) stages of dry beans. The timings were selected based on typical herbicide/fungicide application periods in dry beans where tank contaminations or drift from adjacent fields may occur. Dicamba and 2,4-D choline were applied at 0.1, 1 and 10% of the field use rate for both herbicides. The field use rate was 0.56 kg ae ha-1 of dicamba and 1.1 kg ae ha-1 of 2,4-D choline. Dry bean injury was evaluated 7, 14, 21, and 28 d after treatment (DAT). Dry beans were harvested for yield and adjusted to 18% moisture. There was no difference in injury caused by dicamba or 2,4-D between the varieties. Initial injury was greatest for the early application timing for both herbicides. By 14 DAT, there were no differences in application timing. Over the 28 d that injury was evaluated, dry bean injury was greater from dicamba than 2,4-D. Dry bean injury at this time was greater than 30% from the 10% dicamba treatment and less than 10% from the 10% 2,4-D treatment. Dry bean yield was only reduced from the 10% rate of dicamba at both locations. Yield reductions ranged from 30 to 59%. Even though dry bean yield was only affected by the 10% rate of dicamba, maturity was delayed by several treatments. With some treatments never reaching full maturity. Further research will examine the effects of these treatments on seed quality and germination.

INZENTM SORGHUM WEED CONTROL PROGRAMS WITH DUPONTTM ZESTTM WDG HERBICIDE. Dave Johnson*1, Bruce Steward2, Jeffrey Krumm3, Eric Castner4, Richard Edmund5, Robert Rupp6, Victoria Kleczewski7, Clifton Brister8, Stan Royal9, Bob Williams10, Dan Smith11, Kenneth Carlson12; 1DuPont, Des Moines, IA, 2DuPont Crop Protection, Overland Park, KS, 3DuPont, Hatings, NE, 4DuPont, Wetherford, TX, 5DuPont, Little Rock, AR, 6DuPont, Edmond, OK, 7DuPont, Chesterton, MD, 8DuPont, Donna, TX, 9DuPont, Girard, GA, 10DuPont, Raleigh, NC, 11DuPont, Madison, MS, 12DuPont Crop Protection, Ankeny, IA (184)

THE VALUE OF SALVAGE WEED CONTROL IN GRAIN SORGHUM. Curtis R Thompson*, Dallas E. Peterson; Kansas State University, Manhattan, KS (185)

Sorghum hectares continue to slowly decline over time in Kansas and other sorghum growing areas of the US. This decline in acres is in part due to the difficulty growers have effectively managing problem weeds. Sorghum grain is often marketed for 90% that of corn, thus, being lower yielding than corn, often can be less profitable. In dry climates, sorghum tolerates drought better than corn and can be more productive and profitable than corn in these areas. Dry conditions often lead to poor activation of preemergence applied herbicides. Thus many sorghum growers attempt to reduce inputs and plan postemergence herbicide programs only. This frequently leads to rapidly growing Palmer amaranth and other broadleaf weeds that quickly get too large for adequate control with the post-herbicide program. Postemergence applied herbicide programs were evaluated on 30- to 40-cm tall sorghum and Palmer amaranth similar in size during 2009, 2011-2015, and 2017. Visual estimations of crop injury and weed control were made two and four wk after application. Sorghum grain was combine harvested following a hard freeze or a pre-harvest herbicide was used to destroy weeds to facilitate combine harvest. The untreated sorghum with no weed control yielded 0.6 t ha-1. Only the carfentrazone + nonionic surfactant treated sorghum yielded similar to the untreated sorghum. Sorghum treated with pyrasulfotole + bromoxynil + atrazine + nonionic surfactant + ammonium sulfate had the highest grain yield in the experiment at 4.55 t ha-1. Additional herbicide actives evaluated in the long-term experiment include 2,4-D ester and amine, dicamba, metsulfuron, and halosulfuron + dicamba. Palmer amaranth was the most yield limiting weed species. Treatments varied in the level of Palmer amaranth efficacy, but no treatment provided more than 86% control and a majority of the treatments provided less than 70% control four wk after application. Treatments that contained pyrasulfotole + bromoxynil or carfentrazone provided greater than 90% control of velvetleaf. Only the treatments containing pyrasulfotole + bromoxynil provided complete control of sunflower. Despite the fact there are no excellent herbicide choices in a sorghum salvage situation, sorghum growers can use these late salvage treatments to help control weeds and likely increase their sorghum grain yields and profitability. The use of preemergence herbicides and timely post herbicide programs applied to small weeds remains the best choice to maximize sorghum yields and profitability.

RANGELAND INVASIVE SPECIES IN KANSAS. Walter H. Fick*; Kansas State University, Manhattan, KS (186)

There are about 6.4 million hectares of rangeland in Kansas. The productivity, forage quality, and species diversity of these rangelands are threatened by invasive species. Three key invasive species in Kansas rangeland include sericea lespedeza (Lespedeza cuneata), Old World Bluestem (Bothriochloa spp.), and saltcedar (Tamarix ramosissima). Sericea lespedeza infests about 202,000 hectares in Kansas, primarily in the eastern two-thirds of the state. Herbicides containing triclopyr or metsulfuron are the most effective at reducing sericea lespedeza populations. During the vegetative stage, triclopyr at 560 to 1120 g ha-1 or triclopyr + fluroxypyr at 300 + 100 to 600 + 200 g ha-1 are recommended. Typical products for treating sericea lespedeza at the bloom stage include 35 to 70 g ha-1 metsulfuron, 21 + 6.6 g ha-1 metsulfuron + chlorsulfuron, and 92 + 16.5 to 110.3 + 19.8 g ha-1 aminopyralid + metsulfuron. A large seedbank of viable seeds allows these populations to recover in about two to three yr following herbicide application. Sheep and goats graze sericea lespedeza more readily than cattle. Recent research on repeated late summer burning has almost eliminated seed production and may reduce stands. Old World Bluestem (OWB) has been found in 102/105 counties in Kansas. Caucasian bluestem was introduced in the 1930s for mine land reclamation, forage crop production, and roadside stabilization. The OWBs are not as palatable as most native grasses and increase when they occur on rangeland. Glyphosate at 2240 g ha-1 and imazapyr at 280 to 560 g ha-1 are being used to control OWB. Saltcedar occurs primarily along the Cimarron, Arkansas, Smoky Hill, and Republican River systems in Kansas. Cut-stump, basal bark, and foliar herbicide treatments can help control saltcedar. Effective cut-stump treatments include 25% solutions of triclopyr applied in diesel and 10% solutions of imazapyr applied in water. Basal bark applications of 10% triclopyr applied in diesel can also be effective. Foliar treatment of saltcedar is best in August and September. High volume foliar applications of 1% imazapyr, 0.5 + 0.5% imazapyr + glyphosate, and 10% imazapic provide good control of saltcedar. Integrated systems generally improve control of invasive species. For instance, burning or mowing sericea lespedeza and Old World Bluestems ahead of herbicide application enhance control.

FEED OR FOE? FORAGE QUALITY OF COMMON WEEDS FOUND IN MISSOURI PASTURES . Gatlin E. Bunton*, Kevin Bradley; University of Missouri, Columbia, MO (187)

Pastures account for approximately four million hectares of land in the state of Missouri. Weeds are the primary pest of pastures and can result in reductions in forage yield and quality. Many weeds are also readily grazed or browsed by cattle but little is known regarding the nutritive value of many of these species. A survey of 66 Missouri pastures was conducted in 2015, 2016, and 2017 to determine the prevalence of weed species across the state and to investigate the nutritive value of common weed species. One 20-m2 area was surveyed for every four ha of pasture, and each sampling area was visited at two-wk intervals from April through September. Weed and representative forage samples were also collected from many of the pastures at each two-wk interval. The weed species collected included common ragweed (Ambrosia artemisiifolia L.), large crabgrass (Digitaria sanguinalis L.), annual fleabane (Erigeron annuus L.), buckhorn plantain (Plantago lanceolata L.), yellow foxtail (Setaria pumila Poir.), horsenettle (Solanum carolinense L.), dandelion (Taraxacum officinale F.H. Wigg.), vervain spp. (Verbena spp. L.), and tall ironweed (Vernonia gigantea Trel.) These species were chosen based on their commonality and abundance across surveyed pastures during the three yr of the survey. Near-infrared spectroscopy was used to predict crude protein and in vitro true digestibility of weed and representative forage samples. When compared over the collection period, many weeds, such as common ragweed, horsenettle, and dandelion, were higher in crude protein and in vitro true digestibility compared to the representative forage sample collected in the same field at the same time. Crude protein levels for common ragweed ranged from 14.2 to 19.4% in 2015 and from 11.4 to 26.1% in 2016. Crude protein levels of common ragweed were higher than that of the representative forage sample from the same location for sampling intervals in 2015 and for the first 10 of 12 collection timings in 2016. Crude protein content of yellow foxtail ranged from 8 to 10.3% and was lower than that of the representative forage sample collected from the same location at all sampling intervals. Large crabgrass crude protein content ranged from 9.1 to 14.3% and was lower than that of the representative forage sample after the first two sampling intervals. The results of this study indicate that some weeds are detrimental to the overall nutritive value of a pasture, but many may be nutritious if grazed.

OPTIMIZING JAPANESE KNOTWEED CONTROL AND ESTIMATING COSTS TO ERADICATE POPULATIONS. Mark Renz*, Chris Bloomingdale; University of Wisconsin-Madison, Madison, WI (188)

Japanese knotweed (Fallopia japonica) and related species/hybrids are nonnative invasive plants that are problematic in natural areas, urban environments, and rights of way. This complex of species are difficult to control and anecdotal information exists claiming the relative efficacy of various treatment methods and timings. Studies conducted between 2012 and 2017 compared the effectiveness of treating Japanese knotweed with 1) different chemicals at differing rates and timings, 2) varying the spray volume and 3) timing of mowing prior to treatment. Herbicides evaluated included imazapyr, glyphosate, triclopyr + 2,4-D, and aminopyralid. Results found that imazapyr (1.1 – 1.5 kg ae ha-1) applied in the summer or fall to resprouting stems that were previously mowed provided the greatest reduction in Japanese knotweed that persisted longer (88% control 18 MAT) than other herbicides. Treatments containing imazapyr were more effective when applied in July than in September. In contrast, applications of aminopyralid (0.12 - 0.25 kg ae ha-1) applied in September to resprouting stems provided 85-92% control at 12 MAT but by 18 MAT percent control was reduced to 15-59%. Treatments with aminopyralid were more effective when applied in September (92% control) vs July (85% control) at 12 MAT. Research in 2013 confirmed the effectiveness of aminopyralid and found glyphosate (9 kg ae ha-1) applied at the same timing provided similar control 12 MAT. Subsequent studies 2014-2017 also found that mowing plants the summer prior to fall applications did not improve control with aminopyralid (0.25 kg ae ha-1) and that spray volumes between 187 and 935 L ha-1 provided equivalent control 12 MAT. Spring applications of aminopyralid (0.25 kg ae ha-1) were also found to be less effective (6 % control) compared to fall treatments (94% control) without mowing 12 MAT. While imazapyr was the most effective treatment it also resulted in more bare ground after treatment, as few species emerged 12 MAT. To determine if populations can be eradicated and the cost associated with eradication along roadsides with perennial grass present, eight populations were treated with aminopyralid (0.25 kg ae ha-1) along roadsides throughout southeastern Wisconsin in September 2014, 2015 and 2016. None of the populations were eradicated but cover was reduced > 85% by two YAT with stem densities remaining low (<0.6 stems m2) two and three YAT. Costs for management activities averaged US$2,363 ha-1 (US$961 ac-1), of which 85% were in the first yr and 14% in the second yr. These results suggest that Japanese knotweed and related species/hybrids can be controlled with herbicides, but locations will require monitoring and retreatment for more than three yr to obtain eradication at a significant cost. Site specific factors also need to be considered in selecting an appropriate herbicide and these should be considered prior to conducting management.

TARGETED SEQUENCING OF SSR MARKERS AND ALS-HERBICIDE RESISTANCE ALLELES IN GRAIN SORGHUM AND WEEDY RELATIVES. Jake Ziggafoos*1, Rodrigo Werle1, John Lindquist2, Amit J. Jhala1, David L. Hyten1, Melinda Yerka1; 1University of Nebraska-Lincoln, Lincoln, NE, 2University of Nebraska, Lincoln, NE (189)

Deployment of genetically-engineered (GE) crops has transformed the agricultural landscape in the US and will continue to do so. Commercialization of GE sorghum [Sorghum bicolor (L.) Moench] has been prevented due to concerns about the transfer of GE genes to its weedy relatives through gene flow. Lack of herbicide resistance in particular has reduced industry investment in sorghum despite its genetic potential to reduce water and nutrient inputs relative to corn [Zea mays L.] when used as a biofeedstock. A new, native acetolactate synthase (ALS)-inhibiting herbicide-resistance gene, lacking the regulatory hook associated with GE genes, has been developed in 'Inzen' sorghum by DuPont-Pioneer and is in the final stages of commercialization. Once deployed, this nuclear trait will inevitably transfer to weeds through pollen; thus, an opportunity exists to empirically monitor rates of gene flow to weed populations at a regional scale and document any impacts on weed population biology, especially reproductive success under different cropping systems that include Inzen sorghum. High-throughput screening of weed populations for Inzen alleles will be needed to support large-scale ecological monitoring. Molecular inversion probes (MIPs) were constructed to capture five DNA sequences within ALS known to confer resistance as well as thirty published Sorghum simple sequence repeats (SSRs). These MIPs constitute a robust toolkit for high-throughput, simultaneous detection of resistance alleles present in shattercane [Sorghum bicolor (L.) Moench ssp. drummondii (Nees ex Steud.) de Wet ex Davidse] and johnsongrass [Sorghum halepense (L.) Pers] through crop-to-weed gene flow. Use of these MIPs alongside other developed markers and an appropriate weed population sampling plan following Inzen commercialization will inform responsible deployment of future nuclear traits in sorghum, as few are likely to increase weed fitness or invasiveness more than herbicide resistance.

HERBICIDE OPTIONS IN CORN INTERSEEDED WITH COVER CROPS. Aaron Brooker*1, Christy L. Sprague1, Karen Renner2; 1Michigan State University, East Lansing, MI, 2Michigan State University, E Lansing, MI (190)

The Michigan climate prevents seeding of most cover crop species following corn harvest in October and November. Establishing cover crops in corn from the V2-V7 growth stages is a promising alternative; however, weeds must be controlled in the interseeded corn crop. Postemergence glyphosate application prior to cover crop interseeding is one weed control option, but glyphosate provides no residual activity to stop weed emergence. Soil-applied herbicides and postemergence herbicides with residual activity will control weeds, including glyphosate-resistant species, but may injure interseeded cover crops. The objective of this research is to identify soil-applied and postemergence herbicides for interseeded corn systems. In 2016 and 2017 field studies, 12 herbicides were applied immediately after corn planting. In 2017, 14 herbicides were applied postemergence to corn at the V2 growth stage. Annual ryegrass, Tillage Radish®, and crimson clover were then interseeded at the V3 and V6 growth stages in both field studies. Cover crop injury and percent stand loss were measured 30 d after interseeding and again following corn harvest. In addition to the field studies, 12 preemergence herbicides were applied to pots seeded with each of the three cover crops in the greenhouse. Cover crop density and visual estimations of injury were evaluated 7, 14, 21, and 28 d after seeding. Atrazine, bicyclopyrone, flumetsulam, mesotrione, clopyralid, isoxaflutole, and saflufenacil applied preemergence caused minimal injury to annual ryegrass seeded in V3 or V6 corn. Bicyclopyrone, s-metolachlor, acetochlor, and dimethenamid-P did not injure Tillage Radish®, whereas only bicyclopyrone and flumetsulam were safe to use with crimson clover. Cover crops had poor emergence following postemergence applications of s-metolachlor + mesotrione + glyphosate and thiencarbazone + tembotrione. Mesotrione applied postemergence did not impact cover crop establishment. Herbicide options for cover crop mixtures that provide acceptable weed control are very limited.

CROP TOLERANCE AND WEED SUPPRESSION FROM PRE AND POST HERBICIDES IN INTERSEEDED CORN AND ALFALFA. Mark Renz*1, Chris Bloomingdale1, William Osterholz1, John Grabber2; 1University of Wisconsin-Madison, Madison, WI, 2USDA-ARS Dairy Forage, Madison, WI (191)

Interseeding alfalfa between inter-rows of corn silage can improve soil and water conservation during corn silage production and be a productive forage crop in subsequent years. Previous research has found interseeding alfalfa within a wk of corn planting, followed by prohexadione (a plant growth regulator) applied POST directed to alfalfa results in < 10% corn silage yield loss and increased alfalfa survival and yield in the subsequent year. While the interseeding system is promising, few herbicides are registered for use in both corn and alfalfa thus complicating weed management. While glyphosate is effective when utilizing glyphosate-tolerant varieties, previous research has shown available glyphosate-tolerant alfalfa varieties do not survive as well as select conventional alfalfa varieties in this system. Therefore field trials were established to evaluate alternative herbicides applied PRE or POST and compare if equivalent weed control can be achieved without crop injury and/or yield reductions in corn and alfalfa compared to glyphosate. Two experiments were conducted in Arlington and Prairie du Sac, Wisconsin in 2015-2016. Experiment one focused on PRE herbicide applications and evaluated acetochlor (0.63 or 1.26 kg ha-1), mesotrione (0.14 or 0.27 kg ha-1), s-metolachlor (1.1 or 2.1 kg ha-1), metribuzin (0.11 or 0.21 kg ha-1) and flumetsulam (0.04 or 0.07 kg ha-1) applied after planting corn and alfalfa, but prior to crop/weed emergence; these PRE treatments were compared to a POST application of glyphosate (0.84 kg ae ha-1) when weeds were 10-15-cm tall. Experiment two focused on POST applications and evaluated bromoxynil (0.14, 0.28 or 0.42 kg ha-1), bentazon (0.45 or 0.90 kg ha-1), 2,4-DB amine (0.84 or 1.68 kg ha-1), mesotrione (0.05 or 0.11 kg ha-1) or glyphosate (0.84 kg ae ha-1) applied to weeds that were either 2-7-cm or 10-15-cm tall. Herbicides were applied in randomized complete block design with four and six replications for the PRE and POST experiments, respectively. Yield of corn silage and alfalfa was collected in experiment one only. None injured corn or resulted in any corn silage yield reductions of the PRE herbicides evaluated. Alfalfa was injured with treatments containing mesotrione, metolachlor, and flumetsulam that resulted in > 25% growth reductions two MAT and > 10% yield reduction in alfalfa the following year. Of the treatments that did not injure alfalfa, acetochlor at 1.26 kg ha-1 reduced weed cover 59 % one MAT compared to untreated plots, but suppression did not persist two MAT. Although weed control was reduced compared to the glyphosate treatment, acetochlor at 1.26 kg ha-1 had a similar yield and plant density of alfalfa the following year. In experiment two all herbicides applied POST at the early timing injured alfalfa except 2,4-DB amine and glyphosate, but the later application had reduced to no crop injury from any herbicide. Weed cover was lowest one MAT with glyphosate (<2%), but treatments that contained bromoxynil (6%), 2,4-DB (5%), and mesotrione (3%) provided similar levels of control. While some treatments in the two experiments provided annual broadleaf control equivalent to glyphosate, few gave effective broadleaf and grass control equivalent to glyphosate POST. Results suggest that options for weed management PRE and POST exist that can provide similar weed control, crop safety and productivity as glyphosate used with glyphosate-tolerant varieties. Future efforts will continue to fine tune recommendations and support product registration for use in this novel system.

IMPACT OF COVER CROP PLANTING AND TERMINATION TIME ON CORN PRODUCTION IN SEMI-ARID RAINFED CROPPING SYSTEMS OF WESTERN NEBRASKA. Alexandre T. Rosa*1, Liberty Butts2, Cody Creech3, Roger Elmore1, Daran Rudnick4, Rodrigo Werle1; 1University of Nebraska-Lincoln, Lincoln, NE, 2University of Nebraska Lincoln, North Platte, NE, 3University of Nebraska-Lincoln, Scottsbluff, NE, 4University of Nebraska-Lincoln, North Platte, NE (192)

Cover crops (CC) are becoming popular across the US and producers in semi-arid regions are questioning whether their incorporation is justifiable. Benefits of CC are potential increase in soil fertility, reduced soil erosion, and weed suppression. In dryer environments, CC can use excessive soil water, which may reduce grain yield of subsequent crops. The objective of this study was to evaluate the impact of CC species selection, planting and termination time on biomass production, soil moisture levels, and subsequent corn development and productivity. Treatments consisted of three planting times (three, six, and nine wk after wheat harvest) and four termination times: i) winter-sensitive CC mixture, ii) winter-hardy CC mixture terminated two wk before corn planting, iii) winter-hardy CC mixture terminated at corn planting, and iv) no CC. CC biomass was collected during fall 2016 and spring 2017. Corn was planted early to mid-May 2017. Soil moisture readings were recorded at corn planting from 0-20-cm deep. Corn biomass was collected at V6 growth stage. The experiment was conducted in a randomized complete block design with four replications and established at two locations in western Nebraska (North Platte and Grant). Preliminary results showed that CC planting time has an impact on total biomass accumulation in the fall, but did not have much of an impact on spring biomass accumulation. Soil moisture readings at corn planting time showed similar values for treatments in North Platte, although at Grant there was reduction in soil water content where the winter-hardy CC were late terminated. Corn biomass accumulation at V6 was lower when CC were late terminated, especially at Grant. Results from this study will help us improve the recommendations for CC selection, planting, and termination time under rainfed cropping systems of semi-arid environments in the Great Plains.

A STATEWIDE SURVEY OF STAKEHOLDERS TO ASSESS THE PROBLEM WEEDS AND MANAGEMENT PRACTICES IN NEBRASKA ROW CROPS. Debalin Sarangi*, Amit J. Jhala; University of Nebraska-Lincoln, Lincoln, NE (193)

A total of 425 growers, crop consultants, and stakeholders across Nebraska were surveyed in 2015 to identify the problem weeds and assess the stakeholders' attitude and perception toward weed management practices. The respondent pool consisted of three major groups of stakeholders: growers (36%), crop consultants (27%), and others (37%). This statewide survey was conducted at seven locations in Nebraska (Atkinson, Beatrice, Gering, Hastings, Kearney, Norfolk and North Platte) during Crop Production Clinics, a series of Extension meetings. Results of this survey indicated that common waterhemp (Amaranthus rudis Sauer), horseweed (Conyza canadensis (L.) Cronq.), and kochia (Kochia scoparia (L.) Schrad.) were the most problematic weeds in the state. Evolution and spread of glyphosate resistance in the aforementioned weeds were the major concerns of the respondents, however, they were also concerned about the spread of glyphosate-resistant (GR) Palmer amaranth (Amaranthus palmeri S. Wats.) in Nebraska. In this statewide survey, 60% of the growers reported the presence of at least one GR weeds on their farms. Overall, 61.2% of the total farmed or scouted area were under no-till management, and corn (Zea mays L.) and soybean (Glycine max (L.) Merr) were the major crops (82.3% of the total area surveyed) in Nebraska. Respondents of this statewide survey reported that 2,4-D and glyphosate were the most commonly used preplant burndown herbicides. Atrazine plus mesotrione plus s-metolachlor, and cloransulam-methyl plus sulfentrazone were the most commonly used PRE herbicides in corn and soybean, respectively. Glyphosate was the primary choice of the stakeholders for POST weed management in GR corn and soybean. Only 5.2% of the reported area was planted with glufosinate-resistant crops. This statewide survey also indicated that the majority of the respondents (80%) were concerned about the physical drift or volatility of the auxinic herbicides (dicamba or 2,4-D) following the adoption of new multiple herbicide-resistant crops. In their response, 48% of the respondents indicated the need for more research on better management of herbicide-resistant weeds in Nebraska.

DIFFERENTIAL RESPONSE OF A MULTIPLE HERBICIDE-RESISTANT POPULATION OF WATERHEMP TO CHLOROACETAMIDE HERBICIDES. Seth Strom*1, Lisa Gonzini1, Charlie Mitsdarfer2, Adam Davis3, Dean E Riechers4, Aaron Hager1; 1University of Illinois, Urbana, IL, 2Univ. of Illinois, Urban, IL, 3N-319 Turner Hall, Urbana, IL, 4Univ of Illinois Crop Science, Urbana, IL (194)

Since their discovery in the 1950s, chloroacetamide (Group 15) herbicides have remained an important resource for preemergence (PRE) control of annual grasses and small-seeded broadleaf weeds in corn and soybean. During previous research, resistance to HPPD-, ALS-, PPO-, and PSII-inhibiting herbicides along with 2,4-D was characterized in a population of waterhemp (Amaranthus tuberculatus) from Champaign County, IL (designated CHR). This research also documented large differences in control of the CHR population when treated with different Group 15 herbicides. While differences among these active ingredients were expected, the divergence in waterhemp control among

products was greater than anticipated. Based on this observation, field experiments were conducted during the summers of 2016 and 2017 to investigate the differential response of CHR to Group 15 herbicides. Field experiments consisted of two separate studies: 1) a comparison of eight Group 15 herbicides applied PRE at typical 1X rates and 2) a rate titration study that included several Group 15 herbicides at 1/2X, 1X, 2X, and 4X rates. Control, biomass, and stand count data from both years indicated that acetochlor provided the greatest PRE control of this population, while other compounds provided less control. Greenhouse dose-response studies were subsequently initiated to further examine and compare the responses of CHR to acetochlor and s-metolachlor relative to a known sensitive population. Results indicated an eight-fold difference in GR50 values between CHR and a known sensitive population with s-metolachlor PRE, but only a three-fold difference with acetochlor. In addition, seedling survival data indicated a thirty-fold difference in ED50 values between populations treated with s-metolachlor, but only a five-fold difference with acetochlor. These results corroborate previous field results regarding the varying control levels achieved by different Group 15 compounds within the CHR population. Future greenhouse, growth chamber, and lab research is planned to investigate biokinetic factors within the plant and soil that may contribute to this differential response of CHR to Group 15 herbicides.

GLYPHOSATE-RESISTANT COMMON WATERHEMP CONTROL WITH SOIL-APPLIED AND POSTEMERGENCE HERBICIDES IN CORN. Lauren Benoit*1, Peter H Sikkema1, Darren Robinson1, Dave C. Hooker2; 1University of Guelph, Ridgetown, ON, 2University of Guelph, Guelph, ON (195)

HERBICIDE PROGRAMS AND ECONOMICS OF CONTROL OF ATRAZINE- AND HPPD INHIBITOR-RESISTANT PALMER AMARANTH IN GLUFOSINATE-RESISTANT CORN. Parminder Chahal*, Amit Jhala; University of Nebraska-Lincoln, Lincoln, NE (196)

The evolution of a Palmer amaranth biotype resistant to atrazine and 4-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibitor herbicides in southcentral Nebraska is a management challenge for corn growers. The objectives of this study were to investigate herbicide programs for controlling atrazine- and HPPD inhibitor-resistant Palmer amaranth and to evaluate their potential impact on crop yield and net economic returns in glufosinate-resistant corn. Field experiments were conducted for three years (2014 to 2016) in a grower's field infested with atrazine- and HPPD inhibitor-resistant Palmer amaranth near Shickley in Fillmore County, NE. The contrast analysis suggested that pyroxasulfone + fluthiacet-ethyl + atrazine, saflufenacil + dimethenamid-P, mesotrione + s-metolachlor + atrazine, and acetochlor + clopyralid + flumetsulam provided 88 to 97% Palmer amaranth control at 21 d after PRE in 2014-15. In 2016, Palmer amaranth control was 61 to 75% with PRE herbicides. Glufosinate or glufosinate + dicamba applied alone or in a follow-up application of the aforementioned PRE herbicides provided 89 to 99% control at 28, 56, and 72 d after POST in 2014-15 and 72 to 99% control in 2016. Based on contrast analysis, PRE followed by POST and POST-only programs provided higher corn yields (11,026 to 11,427 kg ha─1) and net returns (US$1,423 to US$1,456) compared with PRE-only (7,117 kg ha─1; US$905) and non-treated control (4,197 kg ha─1; US$584) in glufosinate-resistant corn in 2014 and 2016. In 2015, herbicide programs provided higher corn yields (16,348 to 17,149 kg ha─1) and net returns (US$2,168 to US$2,295) compared with non-treated control (11,578 kg ha─1; US$1,612) in glufosinate-resistant corn. It is concluded that herbicide programs with alternate sites of action are available for effective control of atrazine- and HPPD inhibitor-resistant Palmer amaranth in glufosinate-resistant corn.

JUST WHAT DOES BICYCLOPYRONE BRING TO THE PARTY? Ryan Lins*1, Gordon Vail2, Thomas H. Beckett3; 1Syngenta Crop Protection, Rochester, MN, 2Syngenta Crop Protection, Greensboro, NC, 3Syngenta Crop Protection, LLC, Greensboro, NC (197)

The HPPD-inhibiting herbicide bicyclopyrone has been developed for the corn weed control market as a component in active ingredient mixture products (Acuron, Acuron Flexi) and commercially launched in 2015. Mixtures with bicyclopyrone have shown improved weed control compared to products with similar active ingredients (Lumax, Lexar, Zemax). However, as a mixture component, little information is available regarding the activity of bicyclopyrone applied alone. This paper highlights the weed control benefits that bicyclopyrone provides when applied alone and in mixtures.

BIOLOGICALLY-EFFECTIVE DOSE OF TOLPYRALATE APPLIED POSTEMERGENCE FOR ANNUAL WEED CONTROL IN CORN. Brendan A. Metzger*1, Peter H Sikkema1, Darren Robinson1, Dave C. Hooker2, Alan J. Raeder3; 1University of Guelph, Ridgetown, ON, 2University of Guelph, Guelph, ON, 3ISK Biosciences America, Columbus, OH (198)

Tolpyralate is a 4-hydroxyphenyl-pyruvate dioxygenase (HPPD)-inhibiting herbicide under evaluation for post-emergence (POST) weed management in corn. A total of six field studies were conducted in Ontario over a three-year period (2015, 2016 and 2017), to determine the biologically-effective dose of tolpyralate for the control of seven annual weed species. Tolpyralate was applied POST alone at rates ranging from 3.75-120 g a.i. ha-1 or in tank-mixture at a 1:33.3 ratio with atrazine at rates ranging from 125-4000 g ai ha-1. Two industry standards, mesotrione plus atrazine and topramezone plus atrazine were included for comparison purposes. Regression analysis was conducted to determine the predicted tolpyralate, and tolpyralate + atrazine doses required to achieve >90% control of each species eight wk after application. The required rate of tolpyralate [g ai ha-1] for 90% control is presented in parenthesis for the following species: velvetleaf (Abutilon theophrasti (Medik.)) [<3.75], common ragweed (Ambrosia artemisiifolia (L.)) [7.3], common lambsquarters (Chenopodium album (L.)) [5.6], green/redroot pigweed (Amaranthus powellii (S.) Wats.)/(Amaranthus retroflexus (L.)) [8.5], and green foxtail

(Setaria viridis (L.) Beauv.) [15.5], wild mustard (Sinapis arvensis (L.)) [>120] and ladysthumb (Polygonum persicaria (L.)) [>120]. The required rate of tolpyralate plus atrazine [g a.i. ha-1] for 90% control is presented in parenthesis for the following species: velvetleaf [<3.75 + <125], common lambsquarters [<3.75 + <125], common ragweed [6 + 194], green/redroot pigweed [6.1 + 198], wild mustard [7.6 + 245], green foxtail [11.7 + 377] and ladysthumb [13.5 + 436]. Based on these studies, tolpyralate + atrazine, applied POST, at the proposed label rate range of 30-40 + 500-1000 g a.i. ha-1 provides excellent broad-spectrum weed control in corn.

COMPARISONS OF THE WEED CONTROL OF ATRAZINE OR TERBUTHYLAZINE ALONE AND IN STANDARD ATRAZINE TANK-MIXES IN IRRIGATED CORN. Randall S Currie*, Patrick Geier; Kansas State University, Garden City, KS (199)

Terbuthylazine is a subtly different analog of atrazine that was evaluated while atrazine was in development (circa 1952-1958). It has been suggested that it has a somewhat longer residual activity but less postemergence activity than atrazine. The Geigy Corporation felt that atrazine was a superior product and development of terbuthylazine was delayed. Currently in Europe the use of atrazine is banned and terbuthylazine is used in its place. It has been suggested that terbuthylazine presents a somewhat more friendly ecological profile. Currently the Sipcam Corporation is investigating how it might be used in North American corn production. It was the objective of this study to evaluate terbuthylazine and atrazine at various rates and in popular tank-mixtures. In the summer of 2017 near Garden City, Kansas the following herbicide treatments were evaluated in a randomized complete block design with four replications. Preemergence applications of terbuthylazine at 0.49, 0.81, and 1.09 kg ha-1 were compared to atrazine at 1.12 or 2.24 kg ha-1 or s-metolachlor at 2.18 kg ha-1 as well as tank-mixtures of 0.72 kg ha-1 of terbuthylazine or 1.12 kg ha-1 of atrazine with 1.85 kg ha-1 of s-metolachlor and/or 0.11 kg ha-1 of mesotrione. Postemergence applications included terbuthylazine at 0.81 kg ha-1 or atrazine at 1.83 kg ha-1 with 1.55 kg ha-1 glyphosate, or 0.56 kg ha-1 of 2, 4-D ester. Although preemergence applications of 2.24 kg ha-1 of atrazine provided numerically superior Palmer amaranth control to any rate of terbuthylazine or any lower rate of atrazine at 88 d after planting (DAP), no triazine-alone treatment provided greater than 86% control. By 174 DAP, 2.24 kg ha-1 of atrazine was still providing 83% Palmer amaranth control while all other triazine-only treatments had declined to less than 63%. The addition of s-metolachlor to terbuthylazine or atrazine elevated control to 85% and 95%, respectively. The addition of s-metolachlor and mesotrione to terbuthylazine or atrazine elevated Palmer amaranth control to greater than 95% at 174 DAP. The addition of s-metolachlor and mesotrione similarly elevated green foxtail control from 70% to 95% at 174 DAP. Crabgrass control followed a similar pattern. Early postemergence tank-mixtures of terbuthylazine or atrazine with glyphosate had more than twice the yield of the highest atrazine treatment. They were the highest yielding treatments and were not different from each other. Although it is difficult to draw strong conclusions based on a single study, these results suggest that terbuthylazine might be substituted for atrazine with little decline in weed control. Further, traditional atrazine-based tank-mixtures would be needed to provide acceptable weed control.

IMPLEMENTATION OF VARIABLE RATE HERBICIDE APPLICATIONS BASED ON SOIL PHYSICAL PROPERTIES. Garrison J. Gundy*, J. Anita Dille, Antonio R. Asebedo; Kansas State University, Manhattan, KS (200)

Preemergence (PRE) applications of soil-applied herbicides are traditionally used to minimize weed emergence and early season growth and provide season-long weed control. Producers are also relying heavily on soil-applied herbicides for controlling herbicide-resistant weeds in corn management programs. Weed control efficacy of soil-applied herbicides is greatly influenced by soil properties including soil organic matter (SOM) and texture due to adsorption that impacts bioavailability. There are also many concerns of soil-applied herbicide residues being found in ground water, potentially requiring more regulations that would minimize the availability of these herbicides. Herbicide labels provide multiple application rates to account for bioavailability differences due to soil properties creating a challenge in fields with soil variability. With precision agriculture technologies, variable rate applications (VRA) can be utilized to maximize herbicide effectiveness while minimizing their negative impacts on the crop and environment. A producer’s field in north central Kansas was utilized to develop a procedure for VRA of PRE herbicides based on SOM and apparent soil electrical conductivity (EC) collected by a Veris MSP3 soil mapping system. Two different tank-mixtures were applied, including s-metolachlor, mesotrione, and atrazine or saflufenacil, dimethenamid-P, and atrazine. For each tank-mixture, two algorithms were developed to determine the rate to apply to each plot based on the SOM only or a combination of SOM and soil texture (determined by correlation with EC). A uniform flat rate of each tank-mixture was applied based on the labelled usage rate for the average soil properties across the entire field. Palmer amaranth (Amaranthus palmeri) control was evaluated four, six, and eight wk after treatment (WAT) compared to a non-treated control. For weed control evaluations, both algorithms provided the same amount of Palmer amaranth control as the uniform rate. On average, the tank-mixture of s-metolachlor, mesotrione, and atrazine provided better control than saflufenacil, dimethenamid-P, and atrazine at six and eight WAT. Weed control was much less in areas with a coarse texture and low SOM compared to other areas of the field. On average, lower amounts of herbicide were applied with algorithm based on both SOM and soil texture compared algorithm based on SOM only, but both recommended more herbicide compared to the flat rate. VRA based on both algorithms recommended higher rates in the high SOM, fine textured areas and lower rates in the low SOM, coarse textured areas compared to the flat rate to better follow labeled recommendations.

HARNESS MAX HERBICIDE: A NEW PRODUCT FOR WEED MANAGEMENT IN CORN. Eric Riley*1, Greg

Elmore2, Bob Montgomery3; 1Monsanto, St. Louis, MO, 2Monsanto Company, St. Louis, MO, 3Monsanto, Union City, TN (201)

Monsanto Company has developed a new pre-mixture corn herbicide of acetochlor with safener and mesotrione. The product is branded as Harness® MAX and will be available to growers for the 2018 growing season. Harness® MAX offers excellent residual benefits of acetochlor with the added post-emergence and residual activity of mesotrione for a broadened range of control against tough to control weeds in corn such as amaranths (Amaranthus sp.), common lambsquarters (Chenopodium album), morningglories (Ipomoea sp.) and foxtails (Setaria sp.). Field studies were conducted in 2017 to evaluate weed efficacy and crop response following Harness® MAX alone and with tank-mixtures applied at planting (pre-emergence) and postemergence on 5- and 11-inch corn. Results from these studies indicate that Harness® MAX alone and in combination with tank-mixtures can provide excellent weed efficacy with minimal crop response compared to competitive offerings. For post-emergence weed control, the addition of glyphosate only herbicides will be recommended for improved control of emerged weeds. Harness® MAX will be a valuable product for weed management in corn.

ENLIST DUO LAUNCH EXPERIENCE IN 2017. David Simpson*1, Jonathan Siebert2, Jerome J. Schleier3, David C Ruen4; 1Dow AgroSciences, Zionsville, IN, 2Dow AgroSciences, VO US, MS, 3Dow AgroSciences, Indianapolis, IN, 4Dow AgroSciences, Lanesboro, MN (202)

In 2017 approximately 202,000 hectares of WideStrike® 3 Roundup Ready® Flex Enlist™ cotton was treated with at least one POST application of Enlist Duo® herbicide. An integrated technical and sales support team worked to educate growers on proper application requirements, provide in-season recommendations and investigate product performance issues. Investigations conducted in 2017 were classified as crop response, weed control, physical drift of Enlist Duo, sprayer cleanout or physical drift of an herbicide other than Enlist Duo. Investigation of crop response revealed the addition of adjuvants increased transient crop response expressed as necrosis. Weed control investigations involved either lack of control of glyphosate-resistant kochia, which is not labeled as controlled by Enlist Duo, or applications to weeds greater than 60-cm tall. Physical drift investigations involved injury to cotton without Enlist trait in fields adjacent to Enlist Duo applications. Physical drift was primarily associated with a lack of understanding of label restriction of do not to not apply if wind is blowing toward an adjacent field of cotton with the Enlist trait. Cotton injury from physical drift displayed the typical pattern of greater injury closest to the application with injury dissipating with distance and distance varying with changes in wind speed during application. No formal complaints were filed with any state regulatory department in 2017 concerning off-target movement of Enlist Duo. When label recommendations were followed for applications, no drift, weed control or crop response complaints were received. In 2018, education of growers and applicators about proper application of Enlist Duo herbicide, with specific emphasis on nozzle selection, pressure, boom height, wind directional buffers to susceptible crops, and measurements of wind direction and speed will continue.

CONTROL OF GLYPHOSATE-RESISTANT WATERHEMP IN ONTARIO WITH THE ROUNDUP READY 2 XTEND CROP SYSTEM. Brittany Hedges*1, Peter H Sikkema1, Darren Robinson1, Dave C. Hooker2; 1University of Guelph, Ridgetown, ON, 2University of Guelph, Guelph, ON (203)

Waterhemp (Amaranthus tuberculatus var. rudis) is a small-seeded broadleaf weed, which emerges throughout the growing season. Glyphosate-resistant (GR) waterhemp was discovered in Ontario in 2014. If left uncontrolled, yield decreases of up to 73% have been observed. Dicamba- and glyphosate-resistant soybean allow for dicamba to be applied pre-plant, pre-emergent (PRE) and/or post-emergent (POST). The objective of this study was to determine the control of GR waterhemp in dicamba-resistant soybean with more than one herbicide mode of action applied PRE or in a two-pass system (PRE fb POST), with glyphosate + dicamba applied POST. At 56 d after application (DAA), glyphosate + dicamba, pyroxasulfone, s-metolachlor + metribuzin, pyroxasulfone + sulfentrazone and flumioxazin + pyroxasulfone controlled GR waterhemp by 44, 80, 87, 91 and 96%, respectively. The addition of glyphosate + dicamba to pyroxasulfone, s-metolachlor + metribuzin, pyroxasulfone + sulfentrazone and flumioxazin + pyroxasulfone PRE controlled GR waterhemp by 84, 89, 91 and 92%, respectively. In a two-pass program, pyroxasulfone, s-metolachlor + metribuzin, pyroxasulfone + sulfentrazone and flumioxazin + pyroxasulfone PRE controlled GR waterhemp by 68, 80, 77 and 84%, respectively. The same PRE herbicides, followed by glyphosate + dicamba POST, improved control of GR waterhemp to 93, 99, 98 and 99%, respectively. In conclusion, the addition of glyphosate + dicamba pyroxasulfone, s-metolachlor + metribuzin and pyroxasulfone + sulfentrazone applied PRE, resulted in a small increase in GR waterhemp control. Additionally, a two-pass program of an effective soil applied herbicide followed by glyphosate + dicamba POST controlled GR waterhemp >85%.

GLYPHOSATE-RESISTANT WATERHEMP CONTROL IN GLUFOSINATE, GLYPHOSATE/DICAMBA, GLYPHOSATE/2,4-D AND MESOTRIONE/GLUFOSINATE/ISOXAFLUTOLE-RESISTANT SOYBEAN IN ONTARIO. Peter H Sikkema*1, Mike G. Schryver2, Nader Soltani1; 1University of Guelph, Ridgetown, ON, 2University of Guelph Ridgetown Campus, Ridgetown, ON (204)

Glyphosate-resistant (GR) waterhemp (Amaranthus tuberculatus var. rudis) (WH) was first confirmed in Lambton County, Ontario, Canada in 2014 and has now been documented in three southwestern Ontario counties. This small-seeded, summer annual, broadleaf weed has an extended emergence pattern, has high genetic diversity, is a prolific seed producer, and is very competitive. In Ontario, WH interference reduced soybean yield 73%. The focus of this research was to determine strategies for GR WH control in glyphosate-, glufosinate-, glyphosate/dicamba-glyphosate/2,4-D- and mesotrione/glufosinate/isoxaflutole-resistant soybean. In GR soybean, at 84 d after application (DAA), a sequential application of pyroxasulfone + sulfentrazone or s-metolachlor + metribuzin PRE followed by acifluorfen or fomesafen POST provided 88-100% control of GR WH. In glufosinate-resistant soybean, at 84 DAA, a sequential application of pyroxasulfone + flumioxazin, pyroxasulfone + sulfentrazone or s-metolachlor + metribuzin PRE followed by glufosinate POST provided 97-99% control of GR WH. In glyphosate/2,4-D-resistant soybean, at 84 DAA, a sequential application of pyroxasulfone + flumioxazin, pyroxasulfone + sulfentrazone or s-metolachlor + metribuzin PRE followed by glyphosate/2,4-D POST provided 99% control of GR WH. In mesotrione/glufosinate/isoxaflutole-resistant soybean, at 84 DAA, a sequential application of mesotrione + metribuzin or isoxaflutole + metribuzin PRE followed by fomesafen POST provided 90 and 98% control of GR WH, respectively. This research indicates that the use of alternate herbicide-resistant soybean cultivars provides possible weed management solutions for the control of GR WH in soybean.

EVALUATION OF WEED MANAGEMENT AND GRAIN YIELD IN SIX SOYBEAN SYSTEMS. Matthew C. Geiger*1, Ron Krausz2, Karla Gage3; 1Southern Illinois University, Shattuc, IL, 2Southern Illinois University, Belleville, IL, 3Southern Illinois University, Carbondale, IL (205)

Shifts toward herbicide-resistant weed populations in row-crop agriculture are a widespread epidemic. Sequential and untimely applications of glyphosate, acetolactate synthase-inhibitors, and other herbicide site of action groups, have led to the selection and spread of herbicide-resistant weed biotypes. New soybean systems with resistance to auxinic herbicides, along with proprietary herbicide formulations, have been developed to combat resistance issues in soybean production. These new technologies were assessed for weed control efficacy in standard herbicide programs and grain yield over two years at two sites, in both conventional- and no-tillage systems. New technologies were assessed alongside technologies which have been available for several years. At site one, where conventional-tillage was used, there were few differences in weed control when a preemergence (PRE) followed by (fb) postemergence (POST) herbicide program was used. Soybean systems provided 87% or higher control of Ambrosia trifida, Amaranthus tuberculatus, Setaria faberi, Xanthium strumarium, and Abutilon theophrasti; and with the exception of conventional soybean, soybean systems provided 88% or more control of Ipomoea hederacea. The results of the orthogonal contrasts analyses for 2016 grain yield suggested that there was no difference between soybean systems; only herbicide program was significant. In 2017, there were differences for both herbicide program and soybean system. TIR1 auxin inhibitor- and glyphosate-resistant soybean systems provided an average yield of 2538 kg ha-1, while glufosinate-resistant and conventional soybean provided average yields of 1820 kg ha-1 and 1748 kg ha-1, respectively. Further, 2,4-D-resistant soybean provided higher yield than dicamba-resistant soybean. At the no-tillage site, when using PRE fb POST herbicide programs, there was 85% or higher control of Amaranthus tuberculatus and Panicum dichotomiflorum provided by soybean systems. In 2017, the glufosinate-resistant soybean system provided less control of Panicum dichotimoflorum than other soybean systems. Amaranthus tuberculatus and Ipomoea lacunosa control was equal for soybean systems when using PRE fb POST programs. Orthogonal contrasts for grain yield indicate there was a herbicide program interaction for both years. In 2016, there were no differences between soybean systems for grain yield with the exception of increased yield provided by 2,4-D-resistant soybean relative to dicamba-resistant soybean. In 2017, first- and second-generation glyphosate-resistant varieties provided higher yield than TIR1 auxin inhibitor-resistant varieties. The conventional soybean system provided an average yield of 2868 kg ha-1, while glufosinate-, T1R1 auxin inhibitor-, and glyphosate-resistant soybean systems provided average yields of 2516 to 2538 kg ha-1. Although soybean system was significant for the control of Ipomoea hederacea in 2016 and Panicum dichotomiflorum in 2017 when using PRE fb POST herbicide programs, herbicide program interactions suggest that soybean system choice may be of less importance than using broad spectrum PRE herbicides followed by timely POST applications. Grain yield data indicate that while proper weed control is important, optimum grain yield is achieved when soybean variety selection is based upon yield potential in addition to herbicide-resistance trait.

XTENDIMAXR HERBICIDE WITH VAPORGRIPR TECHNOLOGY UPDATE. Jeffrey E. Herrmann*; Monsanto, St. Charles, MO (206)

WEED CONTROL WITH XTENDIMAX® HERBICIDE WITH VAPORGRIP® TECHNOLOGY IN ROUNDUP READY® XTEND CROP SYSTEM. Neha Rana*; Monsanto Company, St Louis, MO (207)

Monsanto Company has developed formulations containing dicamba for use in the glyphosate- and dicamba-tolerant crops. XtendiMax® with VaporGrip® Technology was registered for commercial over-the-top use by the US Environmental Protection Agency in 2016 and is a key component of glyphosate- and dicamba-tolerant cropping systems. Field trials were completed in 2017 to evaluate weed efficacy and crop safety of several of the approved tank-mixtures with XtendiMax® with VaporGrip® Technology in glyphosate- and dicamba-tolerant soybeans. Results indicated improved control of glyphosate-resistant weed species, as well as other broadleaf and narrowleaf weed species including amaranths (Amaranthus sp.), common lambsquarters (Chenopodium album), morningglories (Ipomoea sp.) and foxtails (Setaria sp.).

SIMULATED TANK CONTAMINATION WITH 2,4-D AND DICAMBA ON DICAMBA- AND GLYPHOSATE-RESISTANT SOYBEAN VARIETIES. Nicholas C. Hayden*1, Julie M Young2, William G. Johnson1, Aaron Hager3, Shawn Conley4, Kevin Bradley5, Lawrence Steckel6, Dan Reynolds7, Jason Norsworthy8, Greg R Kruger9, Bryan G. Young1; 1Purdue University, West Lafayette, IN, 2, Brookston, IN, 3University of Illinois, Urbana, IL, 4University of Wisconsin, Madison, WI, 5University of Missouri, Columbia, MO, 6University of Tennessee, Jackson, TN, 7Mississippi State University, Starkville, MS, 8University of Arkansas, Fayetteville, AR, 9University of Nebraska, North Platte, NE (208)

The adoption of dicamba-tolerant soybean technology has led to an increased potential for dicamba-sensitive varieties to be subjected to off-target dicamba movement. Soybean resistant to 2,4-D will be commercially available for the first time in 2018 and there is a possibility that sprayers may become contaminated with these auxin herbicides. Tank contamination of dicamba has been reported as a common problem that led to injury to dicamba-sensitive soybean in 2017. Therefore, field trials were conducted at multiple universities to evaluate the effect that dicamba and 2,4-D have on dicamba- and glyphosate-tolerant soybeans. A second objective was to determine if the soybean response to 2,4-D would be altered by a simultaneous application of glyphosate and dicamba at full rates on dicamba-tolerant soybean. A dose range for both dicamba and 2,4-D were applied to glyphosate-resistant soybean to establish a baseline for the extent of soybean injury and yield loss for these herbicides. Full rates of glyphosate plus dicamba were applied with a full dose range of 2,4-D on dicamba-resistant soybean to investigate the combined effects of these herbicides on soybean injury. Plant height, percent visual injury, growth stage, and the Behrens and Lueschen scale index were recorded 14 and 28 d after treatment. Nodes per plant, reproductive nodes per plant, pods per plant, pods per node, 100 seed mass, and total seed mass were recorded for ten plants from each plot at harvest, as well as soybean population, plant height, and grain yield for the center two rows of the four-row plots. Yield loss from dicamba applied to glyphosate-resistant soybean at both the V2 and R1 growth stages was not evident for rates up to 5.6 g ae ha-1. Soybean yield loss was first evident for dicamba at 56 g ha-1 and markedly more pronounced (> 50% yield loss) for the application on R1 soybean than at the V2 growth stage. Yield loss on glyphosate-tolerant soybean with 2,4-D was not evident for rates up to 56 g ae ha-1. Soybean yield loss was first observed with 2,4-D applied at 560 g ae ha-1. The same trends in yield loss for 2,4-D were evident on dicamba-tolerant soybean, with no influence on the combination of glyphosate plus dicamba with 2,4-D at any rate. Therefore, this research supports previous research that demonstrates approximately a 10X difference in soybean sensitivity between 2,4-D and dicamba for soybean yield loss.

LAUNCHING ROUNDUP READY XTEND SOYBEAN IN A WET AND WINDY YEAR: PERSPECTIVES FROM INDIANA. Joe Ikley*1, Bill Johnson2; 1Purdue University, West Lafayette, IN, 2Purdue University, W Lafayette, IN (209)

The eastern Corn Belt has many populations of weeds that are resistant to glyphosate, PPO-inhibiting, and ALS-inhibiting herbicides. Some populations are resistant to all of those herbicide groups, which limits effective postemergence in-crop control options in soybean to glufosinate in glufosinate-tolerant soybean, or dicamba in dicamba-tolerant soybean. In Indiana, 526,000 hectares of dicamba-tolerant soybean were planted in 2017, which represents 24% of soybean hectares in the state. This high rate of adoption was in part to help control multiple herbicide-resistant populations of waterhemp, horseweed, Palmer amaranth, and giant ragweed. Across the US, there were more than eight million hectares of dicamba-tolerant soybean planted in 2017, representing the largest launch year of a soybean technology in US history. Subsequently, over 1.4 million hectares of non-dicamba-tolerant soybean were damaged by off target movement of dicamba throughout the growing season. Many states broke their all-time record number of pesticide off-target movement complaints. In Indiana, there were over double the previous record of pesticide drift complaints in a given year. The Office of Indiana State Chemist (OISC), which administrates pesticide laws and drift complaints, estimates that only 1 in 5 actual cases of dicamba drift may have actually been turned in to the agency. Indiana had a wet and cool spring, which made planting and early season weed control difficult across most of the state. Several million hectares of corn and soybean were planted in the last two wk of April before the weather in May then turned cool and wet, which limited field activities for most of May. Planting and replanting continued from late May through early July across the state, just as many postemegence herbicide applications were being applied. June remained wet, and most d where the soil was fit for equipment traffic ended up being very windy. On June 19th the OISC received its first complaint of dicamba moving from a dicamba-tolerant soybean field, and complaints continued through the end of August. The labels for approved dicamba products in dicamba-tolerant soybean have very strict language with regards to environmental conditions where applications are allowed. The windy conditions throughout the month of June often did not allow applications of the dicamba products. July was not as windy as June, and in many cases it was not windy enough to spray Xtendimax or FeXapan which require a minimum wind speed of 5 km hr-1. As a result, Indiana applicators had very limited hr to legally use these products. While adoption of dicamba-tolerant soybean technology is expected to grow as producers continue to battle multiple herbicide-resistant weeds, challenging weather in future yr like Indiana experienced in 2017 could limit the number of hectares that can legally be sprayed with approved dicamba products.

SURVEY OF NEBRASKA SOYBEAN PRODUCERS ON DICAMBA USE DURING THE 2017 GROWING SEASON. Rodrigo Werle*1, Amit Jhala1, Robert N Klein2, Christopher Proctor1, Jenny Rees3; 1University of Nebraska-Lincoln, Lincoln, NE, 2University of Nebraska, North Platte, NE, 3University of Nebraska-Lincoln, York, NE (210)

In 2017, the dicamba and glyphosate-tolerant soybeans became fully available to US soybean producers. In August and September of 2017, a survey was conducted with 312 producers from 60 Nebraska soybean-producing counties (either online via SurveyMonkey or during the 2017 Soybean

Management Field Days held at four locations across Nebraska) with the objective to understand adoption and perceptions regarding the dicamba-tolerant technology. The survey contained 17 questions and was divided in three parts: i) demographics, ii) dicamba application in dicamba-tolerant soybeans, and iii) dicamba injury to non-dicamba-tolerant soybeans. According to results, 20% of the soybean hectares represented in the survey were planted to dicamba-tolerant soybeans in 2017; the dicamba-tolerant soybean hectares are likely to double in 2018. Approximately 70% of survey respondents own a sprayer and apply their herbicide programs. More than 90% of respondents who adopted the dicamba-tolerant technology reported improvement in weed control in 2017. Approximately 60% of respondents used dicamba alone or glyphosate + dicamba for postemergence weed control in dicamba-tolerant soybeans; the remaining 40% added an additional MOA to the POST tank-mixture. Survey respondents used one of the approved dicamba formulations for application in dicamba-tolerant soybeans. Results indicate that late POST dicamba applications (e.g., July) were more likely to result in injury to neighboring non-dicamba-tolerant soybeans when compared to early POST applications (e.g., May and June). According to respondents, off-target dicamba movement resulted not only from applications in dicamba-tolerant soybeans but also from applications in corn. Approximately 50% of respondents noticed dicamba injury on their non-dicamba-tolerant soybeans, which represented 13% of the total non-dicamba-tolerant soybean hectares surveyed. However, 7% of producers who observed dicamba injury in non-dicamba-tolerant soybeans filed an official complaint with the Nebraska Department of Agriculture. Although the technology allowed producers to achieve better weed control during the 2017 growing season, it is apparent that effective resistance management techniques are needed to maintain the effectiveness of the technology. Our recommendation is for producers to not rely exclusively on dicamba for POST control of glyphosate-resistant weeds. Additionally, applying dicamba early POST reduced the likelihood of off-target movement. Educating producers on proper application of dicamba will be of extreme importance to reduce off-target dicamba movement during the 2018 growing season.

INVESTIGATIONS OF THE ROLE THAT WEATHER AND ENVIRONMENTAL CONDITIONS PLAYED IN OFF-TARGET MOVEMENT OF DICAMBA IN 2017. Mandy Bish*, Kevin Bradley; University of Missouri, Columbia, MO (211)

In 2017, more than 1.4 million hectares of soybean were estimated to be damaged by off target movement of dicamba and more than 2,700 dicamba-related injury investigations are being conducted by various state departments of agriculture. In many incidences, the causal agent of dicamba movement has been identified as factors related to physical drift (wind speed, improper nozzles, boom height, etc.). In other incidences further investigations have yet to identify contributing factors that resulted in off-target dicamba movement. The objectives of this on-going research are to assess weather and environmental factors surrounding the d of and the d following dicamba applications in order to identify any consistencies between conditions that may explain off-site dicamba movement. A data set is being assembled that contain incidences surrounding successful dicamba applications where the herbicide stayed on-site, and incidences in which dicamba moved off-target for unknown reasons. Presently 63 cases of unexplained dicamba movement have been identified and compared to 54 applications deemed successful by the lack of observable dicamba injury in the surrounding region. Weather data were retrieved from the nearest university-maintained weather stations. Data included maximum wind speed, maximum air temperature, soil moisture, and precipitation. For Missouri-specific incidences, inversion data was added to test for correlations between atmosphere stability and dicamba movement. Soil pH estimates for each location were retrieved from the National Resources Conservation Service web soil survey. Total soybean hectares within each county was also determined from USDA agricultural census data. The current data set includes information from three states and two countries. A second data set was developed that included the above incidences as well as incidences in which the location is known but application date remains questionable. This second set includes information from five states and 121 incidences of off-target movement, and is being utilized to further explore soil properties and the percent of county in soybean production. Preliminary results from a stepwise regression indicate that the percentage of the county in soybean had the largest effect on whether an incident was reported as "successful" or "off-target." Spearman's correlation was used to study linear relationships between variables for those incidences in which dicamba moved off-target. The coefficient between maximum wind speed and formation of a surface temperature inversion on the d following dicamba application was 0.6122 indicating a positive relationship that was significant ($P<0.0001$). No such relationship existed between surface temperature inversion formation and maximum wind speed for the cases in which dicamba did not move. The results are preliminary but a scenario in which dicamba remains or becomes suspended in a stable air mass following application and then is moved off-site by wind gusts the next d is conceivable. This ongoing research has yet to identify a predominant explanatory variable(s) for incidences in which dicamba moved off-target without explanation compared to incidences when application was successful. Cases continue to be added to the data set, and the latest results will be presented.

INFLUENCE OF APPLICATION TIMING, SURFACE TEMPERATURE INVERSIONS, AND NEW FORMULATIONS ON DICAMBA AIR CONCENTRATIONS FOLLOWING TREATMENT. Shea Farrell*1, Brian R. Dintelmann1, Eric Oseland2, Mandy Bish1, Robert N. Lerch1, Kevin W Bradley1; 1University of Missouri, Columbia, MO, 2University of Missouri, Columbia, IL (212)

Few studies have been conducted to understand the extent to which newly-labeled dicamba formulations are present in the air following application. The objectives of this research are to determine the effects of time of application, surface temperature inversions and new formulations on the concentration of dicamba detected in the air following application. A series of field experiments were conducted near Columbia, Missouri during the summer of 2017. Air samplers were placed equidistantly within 6 x 31 m plots and 31 cm above the canopy prior to dicamba applications to obtain background levels of dicamba. Two or three air samplers were utilized treatment-1 experiment-1 depending on availability of samplers. The samplers were removed immediately prior to dicamba application, and then returned to the treated field 30 minutes following application. Applications were made at the 1X rate for each product, and plots were a minimum of 480 m apart. Glass fiber filters and polyurethane foam substrates (PUF plugs) from the air sampling machines were replaced at set intervals throughout the experiments, which extended up to 72 or 96 hr following application. A methanol wash was used to extract dicamba from the filter paper and PUF plugs, and HPLC-UV was utilized to detect dicamba. The recorded concentrations for each of the air samplers were averaged together in experiments. Preliminary results for two experiments in which Xtendimax plus VaporGrip and Engenia were applied at the same time on the same evening showed the majority of dicamba, regardless of formulation, was detected in the first 0.5 to 8 hr after treatment (HAT); the average concentration of dicamba for the Xtendimax treatment was 26.5 and 31.1 ng m-3 while that for Engenia was 18.4 and 20.5 ng m-3. By 24 to 48 HAT, dicamba levels had declined to less than 3 ng m-3 for each treatment in both experiments. Given spatial limitations and the need to further investigate dicamba concentrations in the air following on-label and off-label applications, only one dicamba formulation, Xtendimax plus VaporGrip, was utilized for the additional inversion experiments. Across two experiments in which Xtendimax plus VaporGrip was applied during inversion conditions, dicamba concentrations were 31.7 ng m-3 0.5 to 8 HAT, which was higher than any other sampling time-point. The 16 to 24 HAT samples, which corresponded to the afternoon of the d following application, resulted in dicamba concentrations of 10.8 ng m-3. Samples from all other time-points averaged less than 5 ng m-3. Xtendimax plus VaporGrip applications were also made on-label and during the d prior to the evening applications. Across two experiments, dicamba concentrations for 0.5 to 8 HAT were 2.64 ng m-3. Concentrations for the 8 to 16 HAT samples, which would correspond to the overnight hours, were 18.24 ng m-3, and these concentrations were higher than those from any other sampling time-point (< 2.63 ng m-3). To quantify the stability of the atmosphere during air sampling times, lapse rates were calculated. The more negative the lapse rate, the more likely the atmosphere is stable or favors inversion-like conditions. Spearman's correlation was used to study relationships between dicamba concentrations, lapse rates, and maximum wind speeds for 0.5 to 8 HAT, 8 to 16 HAT, and 16 to 24 HAT samples in which Xtendimax was applied alone without glyphosate (n=42). A correlation coefficient of -0.54562 (P < 0.0005) was observed between lapse rate and dicamba concentration, suggesting a trend between air stability and dicamba concentration. Another indicator of a stable atmosphere is reduced wind. The correlation coefficient between maximum wind speed and dicamba concentration was -0.69683 (P < 0.0001). These preliminary results indicate that dicamba can be detected in the air following evening applications, and to an extent, concentrations are likely influenced by atmospheric stability. Dicamba detected at 10.8 ng m-3 in the afternoon following application also suggests that volatilization of the chemical is a contributing factor in off-site movement.

EVALUATION OF VOLATILITY OF DICAMBA FORMULATIONS IN SOYBEAN CROP. Debora O. Latorre*1, Dan Reynolds2, Bryan G. Young3, Jason Norsworthy4, Stanley Culpepper5, Kevin Bradley6, Mandy Bish6, Greg R Kruger7, Daniel Stephenson8; 1University of Nebraska-Lincoln, North Platte, NE, 2Mississippi State University, Starkville, MS, 3Purdue University, West Lafayette, IN, 4University of Arkansas, Fayetteville, AR, 5University of Georgia, Titon, GA, 6University of Missouri, Columbia, MO, 7University of Nebraska, North Platte, NE, 8LSU, Baton Rouge, LA (213)

Dicamba injury to non-target plants was a widely covered topic in 2017. Non-resistant soybeans are extremely susceptible to dicamba and damage 1.45 million hectares across the US was reported to have damage from dicamba. New dicamba formulations have made improvements over the previous dicamba formulations for reduction in volatility. There is still volatility with new formulations though. Some additives, such as ammonium sulfate (AMS) can cause the parent acid to disassociate from the salt, which increases the amount of volatility. The objective of this study was to evaluate soybean injury from volatilization of different dicamba solutions. Field studies were conducted as a randomized complete block design with three replications in six different states: Arkansas, Georgia, Indiana, Louisiana, Mississippi, Missouri, and Nebraska. Plots were planted to soybean with each plot consisting of two rows of soybean and had a minimum of two rows of soybean between each plot. Low plastic tunnels six m long were placed over the two soybean rows. Treatments were applied to three flats (60 x 30 cm) filled with soil and water was added to the soil, treated at a remote location, transported to the test site, and placed between the two rows of soybeans in the center of the low plastic tunnel. Treated flats and plastic sheeting were removed 48 hr after application. Treatments were composed of five dicamba formulations (Banvel, Clarity, Engenia, Xtendimax and Roundup Xtend), plus a treatment with Xtendimax and AMS (0.0204 g L-1). An untreated control with no flats was included in the treatment list. Each flat was treated with 2.2 kg ae ha-1 of dicamba and 1.7 kg ae ha-1 of glyphosate (Roundup Xtend was not applied with additional glyphosate). Visual estimation of injury ratings were collected at 28 d after plants were exposure on a scale of 0-100% where zero is no injury and 100 is complete plant death. Data were analyzed with PROC GLIMMIX and means were separated by LSMEANS ($\alpha = 0.05$). In Arkansas, Indiana, and Louisiana soybean plants showed more injury when exposed to Xtendimax + AMS (43%, 31%, and 33%, respectively). In Nebraska, Banvel and Xtendimax + AMS treatments provided 15% injury to soybean plants while in Mississippi, Banvel and Xtendimax + AMS treatments provided 16% and 14% injury, respectively. This study shows that there is volatility associated with dicamba applications. There were differences in the injury associated with volatility between formulations, and Banvel showed the highest risk of volatility between dicamba formulations tested. The addition of AMS increased volatility, showing greater visual injury in soybeans than Banvel. Label requirements and applicators alike need to take every precaution possible to minimize volatility.

DICAMBA VOLATILIZATION FROM FIELD SURFACES. Thomas Mueller*; University of Tennessee, Knoxville, TN (214)

Dicamba-tolerant soybeans have been used in recent years to improve weed control of glyphosate-resistant weeds by the POST application of dicamba. Much interest has been generated by the potential for off-site movement of dicamba, which has resulted in discussions related to the causes of this phenomenon. This report details three field studies, including optimizing field and laboratory conditions to enhance sensitivity and accuracy of dicamba sampling and analysis. The first study showed that diglycolamine salt of dicamba was more likely to volatilize from green plant surfaces compared to either tilled bare ground or dead plant material. The second study showed that newer formulations of dicamba had slightly lower volatility under field conditions compared to the diglycolamine salt formulation. The third study indicated no apparent effect on dicamba volatility of adding a commercial formulation of glyphosate to the BAPMA salt of dicamba, although the surface condition of this study was primarily bare soil and as such a different outcome could be postulated based on varying field conditions. Samples showed dicamba above detectable levels, and the typical pattern of dicamba arising from treated plots was correlated to temperature.

SALIENT FEATURES OF DICAMBA VOLATILITY FROM SOIL. Donald Penner*1, Jan Michael2; 1Michigan State University, E Lansing, MI, 2Michigan State University, East Lansing, MI (215)

Observed volatility of dicamba is a function of the vapor pressure of the particular formulation and numerous environmental factors. The vapor pressure of dicamba acid is 4.5 x 10-3 Pa at 25 C and for the diglycolamine salt of dicamba it is 1.25 x 10-5 Pa at 25 C. The objectives of this research were to document the occurrence of volatility over time after spray application and to determine the role of soil moisture on dicamba volatility. Formulations of dicamba were also considered. Results suggest that dicamba volatility was greater from wet soil than dry and that, in the case of dry soil, it continued over a period of 28d.

SMART MACHINES FOR WEED CONTROL. William L. Patzoldt*, Mac Keely, Erik Ehn, Ben Chostner; Blue River Technology, Sunnyvale, CA (220)

Blue River Technology is bringing the next generation of smart machines to agriculture. With the use of artificial intelligence and machine learning, sprayers are being taught to recognize crops and weeds in real-time, thus allowing the application of herbicides to only weeds with a high degree of accuracy and precision. The See & Spray technology brings several advantages to agricultural producers: 1) reduction of chemical input costs since herbicides would only be used to treat weeds and not crops or soil, 2) allow cost effective herbicide mixtures containing multiple sites of action to combat herbicide-resistance evolution, and 3) allow producers the flexibility to select from a wider array of crop varieties since selectivity and responses to herbicides would be conferred by the machine and not a genetic trait. Since See & Spray machines collect high resolution images from all parts of the field with every pass, it becomes possible to create weed maps that can be used by the producer to make informed decisions about herbicide performance. Prototype See & Spray machines were deployed in 2017 to manage weeds in cotton production. Research will continue in 2018 with expanded efforts to include both cotton and soybean weed management.

REDBALL-HOODED SPRAYERS REDUCE DRIFT - AN OVERVIEW OF UNIVERSITY DRIFT TESTING AND OTHER BENEFITS OF SPRAYING WITH REDBALL HOODS. Steve Claussen*; Wilmar Manufacturing, Benson, MN (225)

More than ever herbicide spray drift continues to be a vital issue for growers, custom applicators and the entire agriculture industry. Redball-Hooded™ Sprayers are a simple and economical approach to reducing herbicide drift. The unique Redball® Gen II Broadcast Hood design helps enclose the spray pattern reducing pesticide exposure to the wind. Spray drift studies conducted by Mississippi State and the University of Nebraska in 2015 and 2016 compared spraying with a Redball-Hooded Sprayer and an open boom using various tip and sizes in wind speeds 11 – 14 km hr-1. The studies concluded that regardless of tip or size the Redball-Hooded Sprayer reduces drift outside the intended spray swath. Other benefits of Redball Broadcast Hoods include more spray delivered on targeted pests, better planning and time management, and improved herbicide-resistance management.

EXTENT OF EARLY-SEASON WEED CONTROL WITH COVER CROPS: A META-ANALYSIS. Anita Dille*1, O. Adewale Osipitan2, Stevan Z. Knezevic2; 1Kansas State University, Manhattan, KS, 2University of Nebraska-Lincoln, Concord, NE (226)

Using cover crops is gaining importance as its use has numerous benefits including improved soil health, reduced soil erosion, and weed suppression. Weeds are most competitive with crops at early growth stages and a management strategy that ensures early-season weed suppression in crops are crucial for crop growth, development, and yield. In this study, we conducted a systematic review and meta-analysis of published research to determine if there is evidence on using cover crops to provide satisfactory weed suppression, by termination of cover crops and up to seven wk after planting of main crop. We also evaluated the impact of cover crops on main crop yields. A total of 51 relevant studies were evaluated, with 94% using fall-sown cover crops; 70% of the cover crops were terminated mechanically as compared to using chemical control. Main crops were planted one to three wk after termination of the cover crops. Overall, cover crops provided early weed suppression by reducing weed biomass (Mean Difference, -43 g m-2 between cover crop and no cover crop) and reducing weed density (Mean Difference, -6.14 plants m-2). Up to seven wk after planting, presence of cover crops maintained a reduction in weed biomass (Mean Difference, -26 g m-2) and weed density (Mean Difference, -27 plants m-2) as compared to no cover crop. These levels of weed suppression were comparable to those provided by chemical and mechanical weed control methods in many cropping systems. The use of cover crops for early season weed suppression had no effect on main crop grain or cotton yields but could increase vegetable crop yields when compared to no cover crop. Decisions about selecting cover crops species type (broadleaf or grass) or number (single or mixtures) were not as important as identifying cover crops with inherently competitive characteristics that suppress weeds, such as high biomass productivity, allelopathic phytotoxicity, and persistent residue.

CONTROLLING HORSEWEED WITH COVER CROP AND HERBICIDE COMBINATIONS. Austin D. Sherman*, Erin Haramoto, J D Green; University of Kentucky, Lexington, KY (227)

Horseweed has been a very prevalent weed for cropping systems in the US. It is widely glyphosate resistant, including the state of Kentucky. There have been reports of horseweed emergence for as many as 246 d out of the year, which provides additional challenge in horseweed management. The objective of this study was to determine the best horseweed management practices prior to soybeans from a fully-factorial combination of these three factors: cover crop (rye or none), fall-applied herbicide (saflufenacil or none), spring applied growth regulator (dicamba, 2,4-D ester, or none). The field that was chosen for this study was fallow in the summer of 2016, prior to the beginning of this study. It has horseweed that historically emerged from the late summer into the early fall, which made the site well-adapted for this study, since a high population of horseweed would be most advantageous to test the above factors. Cereal rye was drilled in at ~90 kg ha-1 on 11/1/2016. Saflufenacil was applied on 11/31/2016 at the rate of 49.91 g ai ha-1. We had two herbicides that were not mixed, dicamba and 2, 4-D ester, that were both applied on 3/9/2017. They were applied at the rates of 281 g ai ha-1 and 800 g ai ha-1, respectively. Throughout the fall, spring, and summer, the density of horseweed was collected. Prior to the spring herbicide applications, three counts were taken: one d after planting the cover crop, roughly one month after the saflufenacil application, and roughly two wk before the spring herbicide applications. The saflufenacil had such a substantial impact on horseweed density that we examined only the cover crop effect. Throughout all of the counts prior to the growth regulator applications, there was less horseweed in the plots with rye than where there was no rye. This indicated that rye was able to successfully suppress horseweed. In March, roughly three wk after the growth regulator applications, we observed that there were still less horseweed in plots without cover crops than with them, excluding the saflufenacil and growth regulator factors. With saflufenacil applications, excluding the cover crop and growth regulator factors, we saw there was less horseweed. Though there is only one yr of data, thus far we have seen that cover crops and saflufenacil are able to reduce horseweed pressure prior to soybeans in a fallow field.

INTERACTION OF APPLICATION TIMING, HERBICIDE ACTIVE INGREDIENT, AND SPECIFIC TARGET-SITE MUTATION ON THE SELECTION OF ALS-INHIBITOR RESISTANT HORSEWEED AND TALL WATERHEMP. Jodi E. Boe*, Haozhen Nie, Bryan G. Young; Purdue University, West Lafayette, IN (228)

The value of acetolactate synthase (ALS)-inhibiting (group #2) herbicides has arguably been reduced in the face of widespread herbicide resistance in weeds. This assessment can sometimes be overstated, suggesting there is no value in the use of group #2 herbicides in Best Management Practices for herbicide resistance. Herbicides from other sites of action with herbicide-resistant weeds have been shown to still provide some level of field efficacy, especially if the resistance mechanism has been characterized to enable low- to moderate-level resistance. Preliminary research has shown that group #2 herbicides can also contribute to field-level suppression of tall waterhemp populations segregating for group #2 resistance. The question remains, what are the implications for resistant biotype selection of group #2 herbicides if they were applied as preemergence (PRE) applications instead of postemergence (POST) and if certain group #2 herbicides select for different resistance mutations than others? Field research was conducted to determine the interaction of application timing (PRE vs. POST) and select group #2 active ingredients for overall efficacy and the influence of these herbicides on the frequency of group #2-resistant individuals in surviving plants. Experiments were conducted at three locations, two in tall waterhemp and one in horseweed, with populations segregating for group #2 resistance. Twenty-five tissue samples were collected from each plot to genotype survivors of PRE and POST applications. DNA was extracted and analyzed for the presence of W574L single-nucleotide polymorphisms on the ALS gene in tall waterhemp and P197L and D376E in horseweed. Chlorimuron applied PRE for tall waterhemp at 11 g ai ha-1 selected for 35% homozygous W574L genotypes and at 44 g ha-1 selected for 70% homozygous W574L genotypes. This, along with a decrease in heterozygous individuals from 65% in the 11 g ai ha-1 rate to 29% in the 44 g ha-1 rate suggests that W574L is semi-dominant in waterhemp and that high labeled rates of chlorimuron applied PRE can overcome the heterozygous W574L-resistance mechanism. Chlorimuron applied PRE selected for a larger overall number of resistant alleles compared to POST applications. The most frequent SNP in the horseweed population tested was P197L and was found at a frequency of 44%. Chlorimuron and cloransulam applied PRE and POST selected for a greater number of resistant alleles than the non-treated checks, but no difference was detected in P197L allele frequency among group #2 herbicide treatments.

CONFIRMATION AND MANAGEMENT OF ALS-RESISTANT DOWNY BROME IN WHEAT PRODUCTION

SYSTEMS OF THE U.S. GREAT PLAINS. Vipan Kumar*1, Prashant Jha2, Phillip Stahlman1, Anjani Jha2; 1Kansas State University, Hays, KS, 2Montana State University, Huntley, MT (229)

Downy brome (Bromus tectorum L.) is one of the most troublesome winter annual grass weed species in wheat across the U.S. Great Plains. In summer of 2016 and 2017, two downy brome populations (R1 and R2) with putative resistance to acetolactate synthase (ALS) inhibitors were collected from two separate wheat fields: one field in Carter County and second field in Toole County of Montana. The main objectives of this research were to (1) confirm and characterize the resistance levels in R1 and R2 downy brome populations to commonly used ALS-inhibiting herbicides relative to a susceptible (S) population, (2) investigate the target site-based mechanism(s) of resistance; and (3) determine the effectiveness of pyroxasulfone alone or in combination with other herbicides for downy brome control in winter wheat. Seeds of S downy brome population were collected from a wheat field near Huntley, MT. Whole plant dose-response experiments indicated that the R1 population was highly resistant (110.1-fold) to imazamox, and low to moderately cross-resistant to pyroxsulam (4.6-fold) and propoxycarbazone (13.9-fold), respectively, but susceptible to mesosulfuron. However, the R2 population was cross-resistant to all four ALS-inhibiting herbicides, i.e., imazamox, propoxycarbazone, pyroxsulam, and mesosulfuron. The nucleotide and amino acid sequence analyses showed that Ser653Asn and Pro197His substitutions in the ALS genes conferred cross-resistance to ALS-inhibiting herbicides in the R1 and R2 downy brome populations, respectively. This is the first molecular confirmation of target site (ALS gene) mutation at Pro197His in this weed species. In separate field experiments, pyroxasulfone (89 or 178 g ai ha-1) applied preemergence (PRE) alone in the fall provided up to 84% control of downy brome in Clearfield™ winter wheat. Furthermore, pyroxasulfone (89 g ai ha-1) applied PRE in the fall followed by imazamox (44 g ai ha-1) applied POST in the spring had an excellent (99%) end-season control of downy brome. In conclusion, these results confirm the first occurrence of downy brome populations with cross-resistance to ALS-inhibiting herbicides in the US Great Plains' cereal production. Pyroxasulfone applied PRE can be effectively utilized as an alternative site-of-action herbicide for downy brome management in winter wheat.

GENETICS OF DIOECY IN AMARANTHUS. Ahmed Sadeque, Patrick Brown, Patrick Tranel*; University of Illinois, Urbana, IL (231)

Waterhemp (Amaranthus tuberculatus) and Palmer amaranth (A. palmeri) are two of the most problematic weeds in the US. These weeds are particularly adept at evolving herbicide resistance and multiple resistances, in part because of their dioecious nature. Little is known about the molecular basis of gender determination in these species; previous information indicates gender is under genetic control with males being the heterogametic sex, although there are no obvious sex chromosomes. We utilized a restriction-site-associated DNA sequencing (RAD-seq) approach to identify gender-specific markers and to begin to explore the molecular basis of dioecy in the species. Approximately 200 each of male and female waterhemp plants were used to make barcoded RAD-seq libraries, which were then sequenced on the Illumina platform. Approximately one million, unique, 64-base-pair sequences (tags) were recovered that appeared at least ten times in the dataset. Permutation analysis was applied to identify gender-biased tags and the results from the analysis (e.g., more male-biased than female-biased tags) supported the previous conclusion that males are the heterogametic sex. When considering gender-specific tags that appeared in 25 or more individuals, 2754 male-specific tags were observed. Interestingly, using the same criteria, 723 female-specific tags were also identified, although they appeared in only about one-fifth of the females. This observation prompted us to speculate that a cryptic (non-functional) male locus may exist in some female plants. Candidate male-specific tags were selected and used to develop PCR-based markers. Evaluation of these markers across several waterhemp populations demonstrated their male specificity. A similar approach used for waterhemp is now being applied to Palmer amaranth. Preliminary analysis indicates that males are also the heterogametic sex in Palmer amaranth. However, fewer male-specific tags were identified, compared with waterhemp, and no female-specific tags were identified from Palmer amaranth. Ultimately, a better understanding of dioecy in these two species could lead to a novel weed control approach, in which a gene drive is used to manipulate gender ratios.

GENOME-WIDE ANALYSIS OF COPY NUMBER VARIATION IN KOCHIA. Todd A. Gaines*1, Eric Patterson1, Philip Westra1, Dan Sloan1, Patrick Tranel2, Chris Saski3; 1Colorado State University, Fort Collins, CO, 2University of Illinois, Urbana, IL, 3Clemson University, Clemson, SC (232)

To better integrate weed biology in future agricultural challenges, genetic tools including the transcriptomes and the genomes of model weedy organisms need to be developed and made available to the research community. Current model plant species do not have the same traits or complexity as many weedy species making them less effective models. Kochia scoparia is a member of the Chenopodiaceae family, a sister taxon to the Amaranthaceae family. K. scoparia's relatedness to many other important weedy species (including Amaranthus spp.) as well as important crop species (sugarbeet and spinach, both in Chenopodiaceae) makes it a good candidate for developing molecular biology research tools. The large (haploid size of 1.0-1.3 Gb), complex genome of K. scoparia made sequencing and genome assembly a challenge. We utilized Illumina paired-end libraries (160X coverage), Illumina mate pair libraries, and PacBio SMRT cells (9X coverage) to conduct a hybrid-platform draft assembly of the K. scoparia genome (inbred line '7710') containing 711 Mbp in 19,671 scaffolds (N50 61,675 nt). The scaffolds showed high synteny to the sugarbeet genome. Annotation with WQ-Maker identified 47,414 gene models. Illumina resequencing of a second K. scoparia line (glyphosate-resistant 'M32') was used to search for gene copy number variation (CNV) using

CNVator. The expected EPSPS gene duplication was identified, confirming the accuracy of the approach. We identified 3,303 CNVs with greater than 2X read coverage in M32 relative to 7710, with average length 16,780 bp. These findings support our hypothesis that K. scoparia has a highly plastic genome with considerable structural genetic variation among different populations.

APPLYING, INTERVIEWING, AND NEGOTIATING ACADEMIC POSITIONS IN WEED SCIENCE. James J Kells*; Michigan State University, E Lansing, MI (233)

The application, interview and negotiation process for academic positions is complex with important expectations often unwritten. While the specific process varies significantly among universities and position categories, there are several common principles that are universal and important to understand. An understanding of these principles is essential to successfully competing for academic positions. This presentation will define the general position categories for weed scientists at US universities. The formal application and interview process will be discussed in detail. In addition, helpful hints for a successful interview will be provided. The presentation will include advice on negotiation following an offer. The presentation is expected to be informal and interactive with the opportunity for discussion and questions/answers.

A HISTORICAL PERSPECTIVE ON DICAMBA. Bob Hartzler*; Iowa State University, Ames, IA (237)

The auxin-like activity of the phenoxyacetic and benzoic acids was discovered in the early-1940's. The herbicide dicamba was first described in 1958, Velsicol acquired the patent for the molecule, and dicamba was first approved for use in the US in 1962. In subsequent years, the label was expanded for use on a wide range of grass crops and for non-crop areas. Dicamba has been described as either a benzoic acid or carboxylic acid compound, and mimics the activity of indole-3-acetic acid (Group 4 herbicide). According to USDA/ERS data, dicamba was used on less than 10% of US corn acres in 1979. Use increased to 15% of corn hectares by 1990, then as herbicide-resistant weeds spread, dicamba use on corn increased to 28% of hectares in 1995. Prior to the introduction of herbicide-resistant crops and Group 27 herbicides (HPPD inhibitors), dicamba primarily competed with atrazine and 2,4-D for broadleaf weed control in corn. Atrazine was preferred over dicamba and 2,4-D by most farmers due its preemergence use, greater margin of crop safety, and lower risk of off-target injury. Dicamba use was much higher in northern states with high pH soils due to the carryover risk associated with atrazine. Dicamba was used on more that 70% of the 1985 corn hectares in North-Central and Northwest Iowa, compared to 12% of US corn hectares. High pH soils in this region prevented use of atrazine rates greater than 1 kg ha-1 when rotating to soybean or other sensitive crops. The high sensitivity of soybean to dicamba has been an issue since its introduction. In a 1971 University of Illinois Extension bulletin, Dr. Ellery Knake discouraged the use of dicamba due to the risk it posed to adjacent soybean. Behrens and Leuschen published a seminal paper in 1979 reporting on factors that influence volatility of dicamba, including temperature, rainfall following application, application surface (soil vs foliar interception), and formulation. A wide range in volatility was found among the salts of dicamba evaluated. The first dicamba product (Banvel) contained the dimethylamine salt of the parent acid. Over the years, several different salts of dicamba have been introduced, often with the intent of reducing dicamba volatility. Low volatility formulations include Banvel II (sodium) in 1981, Clarity (diglycolamine) in 1990, and most recently Xtendimax/Fexapan with Vaporgrip Technology (diglycolamine) and Engenia (BAPMA). Current research will determine the reductions in volatility achieved with these formulations. Increasing problems with herbicide-resistant weeds have led to an increase in dicamba use, and the introduction of dicamba-tolerant crops will continue this trend. The International Survey of Herbicide Resistant Weeds lists 36 weed species with evolved resistance to Group 4 herbicides, seven of these species are reported to be resistant to dicamba.

OBSERVATIONS OF MIDWEST WEED EXTENSION SCIENTISTS. Aaron Hager*; University of Illinois, Urbana, IL (240)

Labeled formulations of dicamba became commercially available in 2017 for application in dicamba-tolerant soybean and cotton varieties. Three products were granted two-year registrations by the US Environmental Protection Agency (EPA), with renewal contingent upon EPA determining before the expiration date "that off-site incidents are not occurring at unacceptable frequencies or levels." Reports of dicamba exposure to non-target dicot species began early-to-mid June 2017 in areas of northeast Arkansas and southeast Missouri, and were followed approximately two wk later by similar reports across the Midwest. Observations by Extension weed scientists in many states suggested exposure had occurred by several processes, including physical spray drift, dicamba residues dislodged from application equipment, and vapor movement following volatilization. By the end of the 2017 growing season, approximately 2,700 dicamba-related injury investigations were being conducted by officials in 26 states, and an estimated 1.4 million hectares of non-dicamba-tolerant soybean had demonstrated symptoms of exposure to dicamba. In response, US EPA issued several amendments to these product labels designed to reduce exposure of sensitive plant species to dicamba primarily through physical movement (i.e., drift during the application or particle movement during temperature inversions) or via dicamba residues dislodged from application equipment. These amendments do not address exposure through volatility. The scale of off-target incidents in 2017 was unprecedented in the over 50-year history of dicamba, and at least one Midwest Extension weed scientist remains skeptical that recently issued label amendments and additional training will dramatically reduce incidents of off-target exposure in 2018.

THE GOOD THE BAD AND THE UGLY: DICAMBA OBSERVATIONS OF SOUTHERN WEED EXTENSION SCIENTISTS. Larry Steckel*1, Jason Bond2, Joyce Ducar3,

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In trying to manage Palmer amaranth, cotton and soybean growers in Arkansas, the Bootheel of Missouri, Mississippi and Tennessee embraced the dicamba-tolerant weed management system. Roughly 85% of cotton and over 50% of soybean varieties planted in these geographies in 2017 were dicamba-tolerant varieties. The weed control, particularly Palmer amaranth, was very good. Unfortunately, most applicators in those states struggled to keep dicamba in the target field. The Department of Agriculture in each of these respective states were swamped with nearly 1,500 dicamba drift complaints to investigate. Weed scientists from those states estimated 769,000 hectares of non-dicamba-tolerant soybeans alone were damaged by off-target dicamba. This does not count service calls Extension personnel handled on trees, vineyards, truck patches, gardens and homeowner landscaping that exhibited dicamba-injury symptoms. A survey of Tennessee Extension agents concerning the causes of the drift can be categorized into five basic reasons. In listing from least frequent to most frequent cause of dicamba drift in their investigations, tank-contamination was the least found, followed by use of illegal dicamba formulation < dicamba misapplication < spraying into a temperature inversion < Xtendimax or Engenia volatilization. Soybeans that were injured by off-target dicamba were at different growth stages. The ones still in the vegetative growth stages when injury was incurred seemed to recover in a few wk. Soybean fields that were in the flowering stages showed visual symptoms longer. In some cases, less fortunate fields that were drifted on multiple times never did completely recover. The ramifications of off-target dicamba movement are still being assessed and probably will be on-going for years to come. Many sensitive soybean fields that were damaged and exhibited visual symptoms recovered by harvest time and farmers reported little or no yield loss. Still other fields, particularly those drifted on multiple times, were reported by growers to have lost 10 to 20% of their expected yield. Unprecedented levels of dicamba stewardship training took place in all four states prior to the 2017 growing season. For example, in Tennessee alone there were 4,600 applicators who took a 30-min dicamba stewardship training on-line module, there were 16 dicamba classroom training sessions that 2,300 applicators attended, 13 blog posts on UTCrops.com that were accessed over 3,600 times, and 16 in-season YouTube training videos that were viewed over 13,500 times. This plus the education provided by Monsanto and BASF personnel would suggest that increased education alone cannot solve this problem. Dicamba-tolerant cotton was also used extensively in Alabama, Georgia, North Carolina, South Carolina and Texas. Applicators in those states had fewer issues with dicamba trespassing across the landscape. A reason postulated for this was the extensive applicator training conducted in Alabama, Georgia and North Carolina. This no doubt had a positive impact. However, state educational efforts may not be the main reason as applicator training in South Carolina and Texas was not as robust as what occurred in some states with more drift issues. Another possibility mentioned is the dramatically fewer soybean hectares in most of those states. Non-dicamba-tolerant soybean are at risk for drift for over three months while most vegetable crops grown in the Southeast have a much shorter growing season and therefore are less exposed temporally to drift. Other thoughts, such as difference in topography and environment, may be reasons why these states had fewer dicamba problems. The bottom line is no one knows for sure. The US Environmental Protection Agency imposed new regulations for the use of dicamba in dicamba-tolerant crops for the 2018 growing season in an effort to mitigate off-target dicamba movement. These rules specify that applicators must maintain specific records of product use and weather conditions at time of use, dicamba products can only be applied at wind speeds less than 16 km hr-1, new tank clean-out procedures are mandated, and now Engenia and Xtendimax are restricted use herbicides. The new US EPA rules are similar to Missouri and Tennessee emergency rules that went into place in early July 2017. Based upon the fact that many official dicamba drift complaints reported to those states' Department of Agriculture came in after their emergency rules were implemented would suggest that off-target dicamba drift issues and complaints during the summer of 2018 will be significant.

TOWARDS A CLIMATOLOGY UNDERSTANDING OF TEMPERATURE INVERSIONS IN NORTHERN MISSISSIPPI AND IMPLICATIONS FOR DICAMBA DRIFT. Richard Grant*; Purdue University, WEST LAFAYETTE, IN (243)

There have been a substantial number of off-target dicamba-related injury claims across the Midwest and South. It is believed that many of these off-target injuries have occurred during temperature inversions (when the air is cooler at the surface than above the surface). Inversions typically develop either during the night under clear skies (radiation inversion) or during d or night when warm air is brought in due to either large-scale and local-scale weather conditions (advection inversion). The wind, radiation, and temperature conditions differ between the types of inversion. An analysis was conducted of the frequency, type, and characteristics of inversion hr defined as a significant difference (a = 0.05) in temperature between measured surface temperature and air temperatures at 1.5 m height over the period May 15 through June 30 at five National Oceanic and Atmospheric Administration (NOAA) National Reference Climate Stations from Mississippi to South Dakota. Supporting evidence for the type of inversion was drawn from analysis of corresponding NOAA National Daily Weather Maps. Analysis of the measurement records showed: 1) many inversions occur during winds greater than one m s-1 and are a result of warm air advection, 2) that there were more inversion hr at three of the five locations in 2017 compared with 2014-2016 with negligible changes for the other two, and 3) that the change in inversion hr between 2014-16 and 2017 was related to latitude. Some implications to the risk of off-target injuries during these inversions will be discussed.

UNIVERSITY RESEARCH ON DICAMBA VOLATILITY.
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The commercialization of dicamba-tolerant soybeans in 2017 and associated applications of dicamba herbicide has generated substantial attention and concerns related to off-target movement (OTM) of dicamba to sensitive plants. Some arguments suggest the OTM of dicamba was a direct result of applicators not following all herbicide label requirement to perform safe applications. Conversely, some applications of dicamba that were reported to follow label directions still resulted in OTM of dicamba to adjacent sensitive plants. The current, and recently revised, label requirements for dicamba applications in dicamba-tolerant soybean are focused mostly on minimizing the movement of physical spray particles during the application process, which will be referred to as primary drift hereafter. Research and education to limit OTM of spray particles has been the subject of research for several decades, especially physical drift considering wind speeds and the droplet size spectra created during the herbicide application. Secondary herbicide drift occurs following the spray application and can be in the form of 1) spray particles suspended in the air, potentially from the presence of a temperature inversion during the application, 2) the generation of dicamba vapor from target surfaces followed by OTM, and 3) dicamba attached to soil particles or dust moving in the wind. The academic community has voiced concern and raised questions about the factors that drive secondary herbicide drift. To address the issue of secondary drift from dicamba applications, several universities have recently conducted research in this area: University of Arkansas, Mississippi State University, University of Tennessee, University of Missouri, University of Nebraska, and Purdue University. Below is an incomplete summary of university research investigating, at least in part, dicamba volatility. Another experiment conducted at several universities in 2017 involved the use of plastic tents (low tunnels) positioned over two rows of sensitive soybeans. Dicamba was applied to soil in flats at a remote location and then introduced to the center of the plastic tents to allow for potential volatility to adjacent soybeans. Soil flats treated with Banvel, Clarity, Engenia, and Xtendimax all resulted in adjacent soybean plants with injury symptoms consistent with dicamba; thus, an indirect measure of dicamba volatility from these formulations. Engenia and Xtendimax did result in less soybean injury than the Banvel formulation, but not always less than the Clarity formulation. The soybeans in a treatment that combined ammonium sulfate (AMS) with Xtendimax plus Roundup PowerMax exhibited similar levels of injury from dicamba as the Banvel treatment; thus, the reduced volatility of the Xtendimax formulation was negated when AMS was added. Related research at Purdue University demonstrated nearly a 3X greater potential for dicamba volatility from leaf surfaces than the soil. Overall, these combined experiments demonstrate the potential volatility of all dicamba formulations, with some reductions in volatility depending on the specific dicamba formulation and the target surface. Large-scale experiments were conducted at several sites to simulate applications that approach commercial applications in terms of the area treated and application equipment relative to the typical small plots used for field research. Applications of Engenia and Xtendimax were made according to label directions to areas ranging from one to two hectares within the same field planted to dicamba-sensitive soybean. Two identical sprayers were used as the applications were performed simultaneously to eliminate environmental conditions as a confounding factor between these two treatments. Plastic, 19-L buckets were used to cover and protect soybean plants along downwind transects from primary and secondary dicamba OTM. At two of the experimental locations soybean injury outside of the treated area was evident in two different directions. One direction of drift aligned with the wind direction during the application. The wind direction shifted after the herbicide application and corresponded to the direction of further soybean injury. Soybean injury in two directions from these experiments indicate both primary and secondary drift occurred. Evidence of both primary and secondary dicamba drift occurred at three sites for both dicamba formulations based on the soybean injury from the “bucket” treatments. Secondary dicamba drift was also evident at one location when potted soybean plants from the greenhouse were introduced to the soybean area directly treated with the dicamba formulations, following a minimum of a 30-min waiting period from the end of the spray application. Potted soybean plants introduced from 24 to 36 hr after the application developed injury symptoms indicative of dicamba vapor. This research provides evidence of both primary and secondary OTM of dicamba, with the extent of soybean injury being similar from each type of OTM. In other words, the contribution of soybean injury from primary and secondary OTM can be equivalent and does not support the idea that primary drift will always result in more off-target injury to sensitive plants than secondary drift. Related, yet independent, experiments conducted at two universities corroborate the potential for dicamba volatility occurring over multiple d after application. Furthermore, one of the experiments using potted soybeans that were placed in fields following dicamba applications and then returned to the greenhouse highlighted the potential for plants that have been exposed to dicamba vapor may serve as a source for subsequent dicamba volatility. In summary, research on OTM of dicamba has been a focus of several research efforts across multiple universities. As the dicamba label requirements have evolved, we find most of this research would support the restrictions imposed to prevent the primary drift of spray particles during the application. The factors involved and the potential for secondary OTM of dicamba still remains unclear and the dicamba labels do not adequately outline all the necessary considerations to prevent this type of dicamba drift. Future research is justified to provide a greater understanding of how suspended spray particles, dicamba vapor, and dust contaminated with dicamba contribute to secondary OTM.

LARGE SCALE VOLATILITY TESTING: WHAT IS INVOLVED. Jerome J. Schleier*, Pat Havens; Dow AgroSciences, Indianapolis, IN (245)

Pesticide volatility is defined as the movement of pesticide vapors through the air after the application of a pesticide in the field. Pesticide drift is defined as the movement of spray particles during the application or immediately after the spray stops. Volatilization is driven by the vapor pressure and evaporation rate of the pesticide, and can occur for hr or d after application. To measure pesticide volatility a wide variety of micrometeorological measurement methods and theory have been developed to estimate the mass loss and volatilization rate (expressed as mass flux) of pesticides. Micrometeorological methods require that the entire study area have the same surficial characteristics, including the area surrounding the treated site, and that the pesticide under investigation be applied as quickly and as uniformly as possible before any measurements are made. Micrometeorological methods require large treated areas so that the flux measurements can be made in the atmospheric boundary-layer with sufficient upwind fetch so the wind speed and temperature gradients can be accurately characterized. Volatility assessment techniques have been developed using micrometeorology theory and a design that enables accurate characterization of mass loss and volatilization rate of pesticides with low to moderate volatility. Measurements from volatility assessment experiments can be used for modeling off-site movement of pesticides.

HOW TO PROCEED IN 2018: A UNIVERSITY PERSPECTIVE. Kevin W Bradley*; University of Missouri, Columbia, MO (246)

Most university weed scientists would suggest that the off-target movement of dicamba that occurred in 2017 (and in some states in 2016) is incomparable in its scope and scale to any other herbicide drift event in our agricultural history. There is also perhaps no other time in our history when greater divisiveness has existed between chemical companies and university weed scientists, between farmers and chemical companies, between farmers and university weed scientists, and even between individual farmers. In this session, we will discuss some of the potential recommendations and methods by which the industry can move forward in 2018 given the likelihood that dicamba-tolerant cotton and soybean will be adopted to a greater extent next season.

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Keyword Index

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