PROCEEDINGS

WESTERN SOCIETY OF WEED SCIENCE

Volume 69, 2016

ISSN: 0091-4487

OFFICERS AND EXECUTIVE COMMITTEE (2015-2016)

President	**Joe Yenish**
President-Elect	**Kirk Howatt**
Immediate Past President	**Drew Lyon**
Secretary	**Curtis Rainbolt**
WSSA Representative	**Marty Schraer**
CAST Representative	**Phil Westra**
Member-At-Large Public Sector	**Scott Nissen**
Member-At-Large Private Sector	**Michael Hubbard**
Research Section Chair	**Jane Mangold**
Research Section Chair-Elect	**Prashant Jha**
Education & Regulatory Section Chair	**Sandra McDonald**
Education & Regulatory Section Chair-Elect	**Brian Jenks**
Constitution & Operating Procedures Representative	**Corey Ransom**
Webmaster & Web Editor	**David Krueger**
Student Liaison Chair	**Marcel Moretti**
Student Liaison Chair-Elect	**Carl Coburn**
Treasurer/Business Manager	**Phil Banks**

2016

PROCEEDINGS

OF

THE WESTERN SOCIETY OF WEED SCIENCE

VOLUME 69

PAPERS PRESENTED AT THE ANNUAL MEETING

MARCH 7-10, 2016

Hyatt Regency
Albuquerque, New Mexico

PREFACE

The Proceedings contain the written abstracts of the papers and posters presented at the 2016 Western Society of Weed Science Annual Meeting plus summaries of the research discussion sections for each Project. The number located in parenthesis at the end of each abstract title corresponds to the paper/poster number in the WSWS Meeting Program. Authors and keywords are indexed separately. Index entries are published as received from the authors with minor format editing.

This e-document is available at the WSWS website (www.wsweedscience.org) or from the WSWS Business Manager, 205 W. Boutz, Building 4, Suite 5, Las Cruces, NM 88005 (wsws@marathonag.com). Print copies may be ordered from Curran Associates (http://www.proceedings.com/agriculture-conference-proceedings.html) 866-964-0401.

The Minutes of the Board of Directors meetings and the Business Meeting are available at the WSWS website.

Proceedings Editor: Bill McCloskey, University of Arizona

POSTER SESSION **1**

Undergraduate Posters **1**

Impact of Crop Competition on Fitness of Glyphosate-Resistant Kochia (*Kochia scoparia* L. Schrad). 1

Functional Expression of Cytochromes P450 in a Yeast System. 1

Metabolic Resistance to Chlorsulfuron in *Kochia scoparia*. 2

Developing Simple Sequence Repeat (SSR) Markers for *Kochia scoparia*. 2

Project 1. Weeds of Range and Natural Areas **3**

Comparing Two Methods For Monitoring Changes in Canopy Cover of Rangeland Species. 3

Using Web-Based Aerial Imagery to Assist in Targeted Weed Mapping. 4

Remote Detection of Invasive Pine Trees in Hawaii: Advanced Detection and Target Definition. 4

Towards Eradication of Miconia (*Miconia calvescens*) from the Hawaiian Island of Kauai: a History of Detection and Control efforts from the Past 13 Years. 5

Adaptive Management of Perennial Pepperweed for Endangered Species and Tidal Marsh Recovery. 5

Russian Olive Invasion, Removal and Restoration along the Yellowstone River. 5

Native Prairie Response to Aminocyclopyrachlor in the Northern Great Plains. 6

Incorporating Trail and Roadway Corridors into a Plant Community Susceptibility Model. 6

Native Forb Response to Aminocyclopyrachlor in the Greenhouse. 7

Herbaceous Plant Response following an Aerial Application of Aminopyralid and Triclopyr to Honey Mesquite 8

Translocation of Aminopyralid and Clopyralid in Non-vernalized and Vernalized Rush Skeletonweed (*Chondrilla juncea* L.). 8

Indaziflam: Potential New Herbicide to Control Invasive Winter Annual Grasses. 8

Evaluating the use of Thresholds Concepts for Improving Habitat through Cheatgrass Management. 9

Buckhorn Plantain Control in Irrigated Pasture. 9

Solar Tenting as a Tool for Managing Invasive Weeds - A Research Update. 10

Phenology of the Biological Control Agent of Dalmatian Toadflax, *Mecinus janthiniformis* (Curculionidae: Coleoptera), in Utah. 11

Project 2. Weeds of Horticultural Crops **11**

Investigating the Potential of Hay Mulch and AMF Inoculant for Small-Scale Organic Vegetable Crop Production. 11

Mulch and Biochar Impacts on Organic Strawberry Establishment. 13

Irrigation and Nitrogen Fertilization Effects on Weed Encroachment and Persistence in Established Turf. 13

Herbicide Effects on Kurapia (*Lippia nodiflora*). 14

Weed Control in Table Beet Seed Production in the Pacific Northwest. 15

Timing of Linuron Treatments in Potato Production. 15

Breaking Bindweed: A Summary of Three Years of Research in CA Processing Tomatoes. 15

Evaluating Postemergence-directed Applications of Flumioxazin in Chile Pepper............. 17

Response of Walnuts to Simulated Drift of Rice Herbicides. 18

Susceptibility of Italian Ryegrass to Orchard Herbicides in California. 18

Cross-Resistance of *Conyza bonariensis* and *Conyza canadensis* Biotypes Resistant to Glyphosate and Glyphosate-Paraquat. 19

Project 3. Weeds of Agronomic Crops 19

Investigating Glyphosate Resistance Mechanisms in California Junglerice Populations. 19

Survival and Fecundity of Glyphosate-Resistant Kochia with Variable EPSPS Gene Copies in Response to Glyphosate Selection. 20

Physiological Studies of Auxin Herbicide Resistance in *Amaranthus tuberculatus* and *Sonchus arvensis*. 20

Survey of Glyphosate-Resistant Kochia in Eastern Oregon Sugar Beet Fields. 20

Monitoring Herbicide Resistance in Cereal Weeds: A Syngenta Perspective. 21

An Overview of Herbicide-Resistant Weeds in Washington. 22

Predicting and Monitoring Weeds Distributions in Dryland Wheat Using Landsat Data..... 22

Sensitivity of 'Bobtail' Wheat to Flufenacet-Metribuzin. 23

New Liquid Sulfonylurea Herbicides for Cereals. 24

BOLT™ Technology Soybean for Improved Plant-Back Flexibility after Chlorsulfuron plus Metsulfuron-methyl Application in Wheat. 24

Rotational Crops Response to Mesosulfuron/Thiencarbazone Applied in Prior Wheat Crop. 24

An Analysis of Predictor Variables and Sampling Dates in the Estimation of Crop Yield Injury. 25

Dry Bean Grower Survey in Minnesota and North Dakota. 25

Chickpea Tolerance to Herbicides applied at Ground Cracking. 26

Degradation of Soil-Applied Herbicides under Limited Irrigation. 26

Reduced Rates of Metribuzin and Hilling for Weed Management in Potato. 27

Scouring Rush (*Equisetum hyemale*) Control in Sugarbeets. 27

Greenhouse Evaluation of Chemical Control for Mid-Season Weeds in Chile Peppers. 28

Tolerance of Peppermint and White Clover to Dormant Application of Saflufenacil. 28

Integrated Weed Management for Conventional Canola (*Brassica rapa*) in Eastern New Mexico. 29

Palynology of Weedy Species. 30

Hairy Nightshade Seed Production Through the Growing Season. 30

Growth Response of Roughstalk Bluegrass and Tall Fescue to Waterlogging. 31

Project 4. Teaching and Technology Transfer 31

Model-based Software for Teaching Tall Morningglory Seedbank Density Effects on Chile Pepper Production. 31

A look back on the 2015 National Weed Contest hosted by The Ohio State University. 32

Digital Books for Weed Identification. 32

Crop Management Field School. 32

Project 5. Basic Biology and Ecology 33

Evaluation and Development of Physical Drift Reduction Adjuvants, Vapor Drift Reduction Adjuvants and Physical and Vapor Reduction Combination Adjuvants with Several Dicamba and 2,4-D Formulations. 33

Physiological Mechanisms of Shade Avoidance Response in *Beta vulgaris*. 33

Crop Canopy Effects on Growth and Fecundity of Kochia at Different Densities. 34

Measuring Jointed Goatgrass (*Aegilops cylindrica*) Seed Bank Longevity with Stable Carbon Isotopes. 34

Characterization of Vernalization Requirements and Expression of *BdVRN1* in *Bromus tectorum*. 35

Seed Germination Dynamics of Herbicide-Resistant and Susceptible Populations of *Kochia scoparia*. 35

GENERAL SESSION 36

Welcome to Albuquerque. 37

Introduction – Meeting Announcements. 37

Presidential Address. 38

Washington Update. 39

Industry Unrest and Employment Outlook. 43

Medicinal Plants of the US Southwest. 44

PROJECT 1: WEEDS OF RANGE AND NATURAL AREAS 44

Timing Considerations for Optimal Herbicide Control of Mesquite in the Arid Southwest. 44

Ecology and Current Management of Saltcedar and Russian Olive in Arizona. 45

Efficacy and Timing of Low-Rate Herbicide Applications to Herb Robert (Geranium robertianum) in Pacific Northwest Forest Habitat. 45

Effects of Scotch broom removal on resource availability and plant community characteristics in Douglas-fir plantations. 46

Invasive Pine Trees in Hawaiian Natural Areas. A Briefing on Current Experimental Treatments. 47

An Integrated Telemetry System for Herbicide Ballistic Technology (HBT) to Determine Dose To Target and Area Use Rate. 47

Why Does it Take Federal Agencies So Long to Start Treating Their Weeds? 47

Prairie Response to Canada Thistle Infestation. 48

Drawdown Applications for Control of Flowering Rush. 48

Effects of Musk Thistle Management on Forage Quality in Montane Rangelands. 49

Beweeded History 49

Inventory of Multiple Weed Species Using Helmet Based Video. 50

Leafy Spurge Control in Environmentally Sensitive Areas with Quinclorac. 50

Leafy Spurge (Euphorbia esula) Control in Sensitive Sites with Aminopyralid Products.... 51

Changing the Landscape in Western North Dakota with *Aphthona spp.* Flea Beetles. 52

Evaluation of New Herbicides for Dalmatian Toadflax Control. 53

Evaluating Targeted Grazing for Dalmatian Toadflax and Geyer Larkspur Management. .. 53

A 20-year Retrospective Evaluation of Seeding Competitive Perennial Grasses for Dalmatian Toadflax Suppression. 54

Winter Annual Grass Control and Remnant Plant Community Response to Indaziflam and Imazapic. 54

PROJECT 2: WEEDS OF HORTICULTURAL CROPS 55

Biosolarization and Soil Health - A Research Update. 55

Influence of Adjacent Weed Species on Thrips and Iris Yellow Spot Virus in Onion. 55

Exploring a Different Method to apply Dimethenamid-p to Control Yellow Nutsedge in Direct-Seeded Dry Bulb Onion. 56

Effect of Rimsulfuron on Teton Russet Potato Tuber Quality and Yield. 57

Bicyclopyrone Performance in Minor/Specialty Crops. 57

Efficacy and Comparison of Herbicides for Perennial Ryegrass Removal During Spring Transition. 57

Residual Weed Control Performance of Penoxsulam + Oxyfluorfen in California Tree Nuts. 58

PROJECT 3: WEEDS OF AGRONOMIC CROPS 58

Comparing Weed Control Treatments in Conventional, Strip, and No-Tillage Sugar Beet. 58

Evaluation of 2,4-D and Related Herbicides for Pre-emergent Control of *Brassica* Volunteers. 59

Liquid Nicosulfuron Oil Dispersion Herbicide: a New Grass Control Option for Nicosulfuron-Tolerant Grain Sorghum. 59

Competitiveness of Alternative Grain Crops with Weeds in Organic Wheat Production Systems. 60

Management of Grass Weed Species with Soil-Applied Herbicides in Established Grasses Grown for Seed. 60

Potential use Patterns for Pyroxasulfone + Flumioxazin for Grasses Grown for Seed. 61

Crop Safety Assessment of Mutagenesis-derived ACCase Resistant Wheat Lines. 62

Trends in Green Foxtail and Wild Oat Resistance and Implications for Control. 63

Characterization of Multiple Herbicide-Resistant Italian Ryegrass (*Lolium perenne ssp. multiflorum*) Populations from Winter Wheat Fields in Oregon. 63

Efficacy and Crop Tolerance of a New Pyroxsulam WG Formulation for Winter and Spring Wheat. 63

Pyroxasulfone Postemergence Grass Control. 64

Mesosulfuron plus Thiencarbazone for Weed Control in Winter Wheat. 64

Biology and Management of Volunteer Buckwheat in Wheat. 65

Halauxifen-methyl plus Florasulam for Pre-seed Weed Control in Spring Cereals. 66

Bicyclopyrone + Bromoxynil: A New Postemergence Herbicide for Broadleaf Weed Control in Cereals. 66

A New Herbicide for Control of Kochia and other Broadleaf Weeds in Fallow and Wheat. 67

Effect of Winter Wheat Stubble Height on Dry Bean Growth and Development. 67

Venice Mallow (*Hibiscus trionum*) Control in Dry Beans. 68

Effect of Row Spacing, Plant Architecture, and Herbicides on Weed Control in Dry Bean (*Phaseolus vulgaris*). 68

Can EPTC increase POST Heribicide Efficacy? 69

Herbicide Tolerance of Direct-Seeded Guayule (*Parthenium argentatum*). 69

Linuron Weed Control Systems in Eastern WA Chickpea. 71

Performance of Certain Herbicides as Influenced by Novel Adjuvant Systems. 71

Dicamba Droplet Retention on Common Lambsquarters (Chenopodium album) Leaves as Influenced by Nozzle Type, Application Pressure, and Adjuvant. 72

Efficacy of Glyphosate and Dicamba Tank-Mixes in Kochia. 72

Heribicide Programs for Kochia Control in Dicamba-Tolerant Soybeans. 73

Introducing BOLTTM Technology: A New Herbicide System for Cleaner Fields and Greater Management Flexibility in Soybean. 73

Multiple Resistance in Palmer Amaranth in Kansas. 73

Population Genomics of Glyphosate-Resistant Palmer Amaranth (*Amaranthus palmeri*) using Genotyping-by-Sequencing (GBS). 74

Understanding the Genetic Evolution of Glyphosate Resistance in *Kochia scoparia* Populations. 75

Kochia Control in Fallow with Winter versus Early Spring Preemergence Herbicide Applications. 75

Evaluating the Effectiveness of Fall-Applied Herbicides for Kochia Management in Soybean in the Upper Great Plains. 76

Glyphosate Induced Injury to Transgenic Herbicide-Tolerant Alfalfa under Cold Temperatures. 77

Dock (*Rumex* spp.) Control in Red Clover (*Trifolium pratense* L.) with Asulam and 2,4-DB. 78

PROJECT 4: TEACHING AND TECHNOLOGY TRANSFER 78

Using the 2016 Guide for Weed, Disease and Insect Management in Nebraska (EC130) to Improve Pesticide Efficacy and to Manage Spray Drift. 78

Glyphosate: A Modern Day Drifter. 79

Glyphosate Residue, Looking For Love In all The Wrong Places. 80

Are All High Surfactant Oil Concentrate Adjuvants Created Equal? 80

Is Early Detection & Rapid Response the Only Viable Approach for Proactive Herbicide Resistance Management? 81

The Wyoming Restoration Challenge: Participatory Learning in the Information Age. 81

Weed Science in the Twitterverse: Education, Conflict, and Pornbots. 82

PROJECT 5: BASIC BIOLOGY AND ECOLOGY 82

An *in vitro* System for Predicting Herbicide Subcellular Partitioning. 82

High Resolution Physical Mapping of EPSPS Copies in Glyphosate-Resistant *Amaranthus* species. 82

Spatial Genetic Structure and Glyphosate Resistance in *Lolium perenne* ssp. Multiflorum (Italian ryegrass) in California Orchards and Vineyards. 83

Molecular and Genomic Weed Science Research at Colorado State University. 83

Experimental Methods for Confirming Resistance to Synthetic Auxin Herbicides. 83

Using Multiple Sequencing Platforms to Assemble the *Kochia scoparia* Genome. 84

Using RNA-Seq to Explore Dicamba Resistance Mechanisms in *Kochia scoparia*. 84

Economic Feasibility of Supplementing Cornstalk Grazing with Fall-Seeded Forage Crops in Southeast Wyoming. 85

A Depsipeptide from the Pathogenic Fungi *Burkholderia* sp. A396 Targets Plant Histone Deacetylases. 85

Determining Seed Retention of Key Annual Weeds at Wheat Harvest. 86

Response of Light-Grown *Beta vulgaris* to Reflected Far-red Light. 86

Potential Effects of Harvest Weed Seed Control on Wild Oat Populations Based on Demographic Modelling. 87

Fire and Fire Management Impacts on Cheatgrass (*Bromus tectorum*) in Montana. 88

Gene Flow Between Canola and Totsoi. 88

Herbicide Resistance in Hairy Fleabane: the Effects of Region, Season, Size and Methodology on Expression. 89

Mechanism of ALS inhibitor resistance in Shepherd's-purse (Capsella bursa-pastoris). 90

EDUCATION & REGULATORY SECTION 91

Weeds Up Close and Personal: Update. 91

Fortifying Farms and Ranches Against Weed Invasion. 91

DISCUSSION SESSIONS 93

Project 1 Discussion Session: Weeds of Range and Natural Areas 93

Project 2 Discussion Section: Weeds of Horticultural Crops 98

Project 3 Discussion Section: Weeds of Agronomic Crops 100

Project 4 Discussion Section: Teaching and Technology Transfer 102

Project 5 Discussion Session: Basic Biology and Ecology 104

Discussion Section: Education and Regulatory 109

WESTERN SOCIETY OF WEED SCIENCE NET WORTH REPORT 112

WSWS CASH FLOW REPORT 113

WSWS 2016 FELLOW AWARDS 114

Joe DiTomaso 114

Jesse Richardson 115

WSWS 2016 Honorary Member 116

WSWS 2016 OUTSTANDING WEED SCIENTIST – Prashant Jha 117

WSWS 2016 WEED MANAGER AWARD 118

WSWS 2016 PROFESSIONAL STAFF AWARD 119

WSWS 2016 PRESIDENTIAL AWARD OF MERIT – Roland Schirman 120

WSWS 2016 STUDENT SCHOLARSHIP RECIPIENTS 121

Oral Paper Contest Awards – Range and Natural Areas, Horticultral Crops and Teaching and Technology Transfer.. 122

Oral Paper Contest Awards – Agronomic Crops.. 123

Oral Paper Contest Awards – Basic Biology and Ecology 124

Poster Presentation Awards – Range and Natural Areas, Horticultural Crops and Basic Biology and Ecology 125

Poster Presentation Awards – Agronomic Crops.. 126

Poster Presentation Awards – Undergraduate Posters 127

WSWS 2016 ANNUAL MEETING NECROLOGY REPORT.. 128

WSWS 2016 ANNUAL MEETING ATTENDEES – Albuquerque, New Mexico............. 129

WSWS 2016 ANNUAL MEETING – AUTHOR INDEX 138

WSWS 2016 ANNUAL MEETING – KEYWORD INDEX 151

WSWS 2016 ANNUAL MEETING – ABSTRACT NUMBER, PAGE NUMBER INDEX 165

2015-2016 WSWS Standing and Ad Hoc Committees.. 167

POSTER SESSION

Undergraduate Posters

Impact of Crop Competition on Fitness of Glyphosate-Resistant Kochia (*Kochia scoparia* L. Schrad). Jessica A. Bramhall*, Aruna Varanasi, J Anita Dille, Mithila Jugulam; Kansas State University, Manhattan, KS (001)

Kochia (*Kochia scoparia* L. Schrad) is a member of the Chenopodiaceae. Kochia is found throughout Kansas and has become a major weed. Overuse of the herbicides, specifically, glyphosate in Roundup Ready crops in Kansas resulted in the evolution and spread of glyphosate resistance in several weeds including kochia. Crop competition in the presence of glyphosate-resistant (GR) or -susceptible (GS) kochia populations is not known. The objective of this study was to determine the impact of crop competition on the growth and fitness of GR and GS kochia populations. The experiment was carried out using a target neighborhood design with four replications. The growth of GR or GS kochia (target plant) was evaluated under increasing densities of oats (neighbor plants). The density levels include; 20 plants/m^2 (0 neighbor plants+1 target plant), 100 plants/m^2 (4 neighbor plants+1 target plant), 180 plants/m2 (8 neighbor plants+1 target plant). The results of this study suggest that the oat competition had greater effect on height and primary branches compared to photosynthetic efficiency in both GS and GR kochia. As oat competition increased, GR kochia had a greater reduction in plant height, primary branches, and photosynthetic efficiency compared to GS kochia. Overall, GS kochia had the greatest resilience to oat competition compared to GR kochia. These differences maybe attributed more to inherent genetic variability in the two kochia populations. Since the GS and GR kochia were field populations collected from different locations, a direct correlation cannot be made between glyphosate resistance and competitive ability in kochia.

Functional Expression of Cytochromes P450 in a Yeast System. Abigail Barker*, Todd Gaines, Juan L. Argueso, Franck Dayan; Colorado State University, Fort Collins, CO (002)

Cytochrome P450s have been extensively connected to herbicide metabolism in monocots such as wheat and corn, but only recently have been investigated for herbicide resistance in dicot species including Kochia scoparia. They pose a unique threat for the evolution of herbicide resistance in weeds due to the ability of a single P450 to metabolize herbicides with different modes of action, which could mean a reevaluation of the current mode of action system used to recommend herbicide rotation in crops. Gene constructs were synthesized for expression in yeast to study the effects of plant P450s in vivo. The yeast line WAT21 was used because it expresses a plant P450 reductase and is sensitive to chlorsulfuron. A known chlorsulfuron-metabolizing protein from wheat, CYP71C6v1, and the closest homolog in Kochia scoparia were chosen for initial testing to evaluate chlorsulfuron-resistance due to P450 expression in WAT21. A liquid assay was used with chlorsulfuron concentrations from one to one thousand μM and the growth rate of yeast was measured by the OD600 to obtain growth response curves. Results indicate this system has potential to screen new and existing herbicides for cytochrome P450 metabolism.

Metabolic Resistance to Chlorsulfuron in *Kochia scoparia*. Olivia E. Todd*, Todd Gaines; Colorado State University, Fort Collins, CO (003)

Kochia (*Kochia scoparia)* is an invasive weed highly resistant to acetolactate synthase (ALS) inhibitors, such as chlorsulfuron. The genetic mechanism for this resistance has majoritively been reported to be a target-site (TS) mutation in the ALS gene. However, it is suspected that kochia has evolved a non-target site resistance (NTSR) mechanism to the ALS inhibiting herbicide chlorsulfuron in two populations referred to as J9 and J10, collected from eastern Colorado. J9, J10 and two control populations that have the TS mutation were sprayed with chlorsulfuron. Chlorsulfuron treatment included being preceeded with and without malathion, an insecticide known to inhibit cytochrome P450 activity, to assess resistance and re-induce susceptibility in J9 and J10. The change in growth following the combination of malathion plus chlorsulfuron in J9 and J10, measured in plant height and biomass following treatment, supports the hypothesis that the candidate populations J9 and J10 have an NTSR mechanism. Analysis of the ALS gene in J9 and J10 revealed no target site mutation, thereby supporting the idea of resistance due to increased chlorsulfuron metabolism.

Developing Simple Sequence Repeat (SSR) Markers for *Kochia scoparia*. Adrian Quicke*[1], Eric Patterson[1], Karl Ravet[1], Philip Westra[1], Patrick Tranel[2], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [3]University of Illinois, Urbana, IL (004)

To date, studies aiming to understand the genetic evolution of weedy species were limited due to the lack of genomic resources. However, the recent emergence of affordable next generation sequencing technologies is enabling the development of genetic studies in non-model organisms such as weedy species. Our group aims to understand the rapid evolution of glyphosate resistance (GR) in *Kochia scoparia* populations throughout the US. This has required the development of appropriate polymorphic DNA markers for kochia. GR is evolving very rapidly, both from temporal and spatial points of view. Therefore, we developed a series of polymorphic Simple Sequence Repeat (SSR) markers. The multiallelic and highly polymorphic nature of SSR markers is of particular value when analyzing closely related kochia populations. We used Roche 454 sequencing to determine partial genomic sequence from a GR *Kochia* plant. We screened the sequence data for the presence of SSR (pentanucleotide repeats) to use as molecular markers for genotyping. Among these SSR markers, we tested for those that are polymorphic among the different geographic populations we have collected. SSR fragments are amplified by DNA Polymerase Chain Reaction (PCR) and DNA product size is analyzed by gel capillary electrophoresis.

Project 1. Weeds of Range and Natural Areas

Comparing Two Methods For Monitoring Changes in Canopy Cover of Rangeland Species.

Heather E. Olsen*, Corey Ransom; Utah State University, Logan, UT (005)

Advances in digital imagery and image analysis technology may provide a more efficient alternative to traditional vegetation monitoring methods. To evaluate the interchangeableness of a more traditional method with an image analysis method, the image analysis software SamplePoint was compared to a line-point intercept method in existing downy brome (*Bromus tectorum*) and Russian knapweed (*Acroptilon repens*) experimental plots in Dinosaur National Monument. The downy brome plots were established in 2010 at two locations within the Monument, the Josie Morris Ranch and Echo Park, with treatments being applied in fall 2010. The Russian knapweed plots were established at one location in 2009 and 2010, with treatments being applied in spring and fall of both years. Additional follow-up herbicide treatments occurred for both experiments in fall 2013. Throughout the studies, line-point intercept had been used to evaluate vegetation changes in response to weed management treatments. Individual species were recorded every 15 cm along the 9 m transect line. The comparison with SamplePoint analysis began in spring 2013. Four photos were taken along the same transect line used for the line-point intercept, with the center of the photos evenly spaced along the line. Images were analyzed in SamplePoint using a 5x5 grid for a total of 25 points per photo, or 100 points per plot. A total of 272 plots were evaluated using both methods for two years (2013-2014). Percent cover for each plot was calculated from the number of points intersected by each species (point-line intercept) or from the number of observations of each species within the grid (SamplePoint) divided by the total number of points or observations made. For each species, paired analysis was conducted to assess the correlation (r^2 value) between methods for estimating percent cover for each experiment in each year of the study. Percent cover estimates for each species, and the change in cover between years for each species, from each method were also compared using a repeated measures ANOVA. Though percent cover methods were significantly correlated between the two methods for some species, overall, the two methods did not agree particularly well for many of the species. In the Russian knapweed study, when there was a significant difference between methods, the SamplePoint method always yielded a higher estimate for bareground, litter, and annual grasses, while the line-point intercept method always resulted in a higher estimate for forbs and perennials. In the downy brome study, when there was only a significant method effect (no method by treatment interaction), the line-point intercept method yielded higher estimates for forbs and bareground and for the change in percent bareground at the Josie Morris Ranch in 2013, for the weedy forbs at both locations in 2014, and for poverty sumpweed (*Iva axillaris*) at Echo Park in 2013. Some treatment by method interactions indicate that vegetation changes due to treatment or other manipulations may affect how well the two methods correlate. In only a few species cases did the two methods estimate change in cover equally well. This study did not investigate the accuracy of either method, rather the interchangeableness of the two methods. It is recommended that once a monitoring method is selected, that method should be used throughout the study.

Using Web-Based Aerial Imagery to Assist in Targeted Weed Mapping. Corey Ransom[1], Heather E. Olsen*[1], James Barnhill[2]; [1]Utah State University, Logan, UT, [2]Utah State University, Ogden, UT (006)

Spread of the invasive annual grass medusahead (*Taeniatherum caput-medusae*) is an increasing concern on northern Utah rangelands and foothills. A method was developed to use free web-based aerial imagery to identify potential areas of medusahead infestation in Morgan County, where the extent of medusahead infestations was unknown. Based on a known infestation for reference, the preferred habitat and unique color of medusahead were used to identify other potential infestations on historical web-based imagery. The potential infestations identified through the imagery were verified or refuted with targeted on-the-ground mapping. Forty-seven of the identified 66 potential infestations were visited and 21 of those sites were positive medusahead infestations. A total of 465 acres were identified as being medusahead infested. Of the other 26 potential infestations, 10 were infested with downy brome, nine were infested with feral rye, and seven were noted as "other" (including native wheatgrasses, rock outcroppings, exposed soil). New, previously unknown, infestations were identified with this method, but overall it was only accurate 45% of the time. Dated aerial imagery, as well as limited imagery from times when medusahead is visible, limit the utility of this method for widespread or comprehensive use. A method using aerial imagery to target potential infestations may be an economical way to confirm suspected infestations, but cannot account for all possible infestations within an area. The results from this targeted inventory were used to help direct management of the previously unknown infestations.

Remote Detection of Invasive Pine Trees in Hawaii: Advanced Detection and Target Definition. Jonathan D. Marshall*[1], Jeremy Gooding[2], Tomoaki Miura[3], James K. Leary[4]; [1]National Park Service, Kula, HI,[2]National Park Service, Pukalani, HI, [3]University of Hawaii, Honolulu, HI, [4]University of Hawaii, Kula, HI (007)

Invasive pine trees (*Pinus spp.*) pose a significant threat to the diverse native ecosystems of Haleakalā National Park. Nearby historical pine plantations, and recent fires, have resulted in an influx of pine seeds into the montane East Maui region. These pine trees are invasive and a threat to montane ecosystems that are crucial habitat for many endangered Hawaiian plants and animals. Due to the remoteness of this region, early detection will be crucial for successful control. Traditional field and airborne reconnaissance methods either lack the ability to comprehensively detect remote incipient populations or are expensive. To improve these capabilities, high spatial resolution satellite multispectral imagery was utilized to detect and map the presence of pine trees across the montane region of East Maui. Land cover classification techniques allowed for the statistical differentiation of pines from surrounding vegetation types. Classification relied on the unique spectral and textural characteristics inherent across the different vegetation types analyzed. The developed protocol allowed for high overall post-classification accuracy (>80%) and enabled population density and extent analysis when used in conjunction with a time series of satellite imagery. The results of this project provide a basis for a remote sensing component to invasive species management at Haleakalā National Park and will allow for improved prioritization of management effort.

Towards Eradication of Miconia (*Miconia calvescens*) from the Hawaiian Island of Kauai: a History of Detection and Control efforts from the Past 13 Years. Kelsey Brock*, Cleve Javier, Bill Lucey; Kauai Invasive Species Committee, Kapa'a, HI (008)

Abstract not available

Adaptive Management of Perennial Pepperweed for Endangered Species and Tidal Marsh Recovery. Brenda J. Grewell*[1], Caryn J. Futrell[1], Michael Forbert[2], Meghan J. Skaer Thomason[1]; [1]USDA-ARS, Davis, CA, [2]West Coast Wildlands, Pacifica, CA (009)

Perennial pepperweed has invaded a wide range of habitat types in the far west. In the San Francisco Estuary, dense infestations have impacted sensitive tidal wetlands and compromised endangered species recovery efforts. An adaptive management effort to reduce perennial pepperweed was initiated by California State Parks at Southampton Bay Wetland Natural Preserve, Benicia. We evaluated management at two spatial scales using large-scale GIS-based assessments of target weed and endangered plant populations, in addition to a habitat-scale field experiment. Our objectives were to 1) assess the marsh-wide distribution and abundance of perennial pepperweed and endangered plant populations by microhabitat types to establish conservation zones and treatment approaches, and 2) evaluate efficacy of foliar-applied glyphosate treatments to perennial pepperweed in three tidal inundation zones and two microhabitat types for four years. Results were used to inform annual management decisions, and to maximize success of weed control while avoiding non-target impacts to endangered plants and ground-nesting marsh birds. In the experiment, weed response measures included live above ground biomass, stem density, % cover, and total non-structural carbohydrate concentration of below ground storage organs. All measured responses were significantly reduced by glyphosate treatments, though the magnitude of treatment effectiveness varied by year and microenvironment. Variation in treatment effectiveness was greatest in mid-marsh inundation zones near slough edges, prompting greater applicator attention to these areas. Marsh-wide, ground-based GPS mapping documented an 84% decrease in perennial pepperweed, with extant stands reduced to trace cover levels and only minor untreated areas remaining at higher cover. During the project, the total occupied area of the endangered plant population increased by over 200%. These results demonstrate that careful, science-based adaptive management can be successful for herbicide suppression of invasive weeds in highly sensitive endangered species habitat. The project now serves as a model for responsible weed management and endangered species recovery.

Russian Olive Invasion, Removal and Restoration along the Yellowstone River. Erin K. Espeland*[1], Jennifer Muscha[2], Merilynn Schantz[1], Robert Kilian[3], Joe Scianna[3], Mark Petersen[2]; [1]USDA ARS, Sidney, MT, [2]USDA ARS, Miles City, MT, [3]USDA NRCS, Bridger, MT (010)

Many areas on the Yellowstone River have converted to dense Russian olive stands, reducing agricultural and ecological value. Controlling Russian olive (*Elaeagnus angustifolia*) is a multi-year commitment, with stump resprouting occurring up to two years post-removal and massive recruitment from seed after that. Restoration after Russian olive removal may take years to establish but can result in reduced weed abundance, particularly when shrubs are transplanted. Area surveys indicate that shrubs may decrease invasibility in this landscape.

Native Prairie Response to Aminocyclopyrachlor in the Northern Great Plains. Blake M. Thilmony*, Rodney G. Lym; North Dakota State University, Fargo, ND (011)

Native prairie response to aminocyclopyrachlor (AMCP) was evaluated at two locations in the northern Great Plains. AMCP altered the plant communities and reduced foliar cover of undesirable species, high seral forbs, and low seral forbs at both locations 10 and 14 months after treatment (MAT). AMCP reduced Canada thistle and leafy spurge in Fargo, ND and eliminated field bindweed, prickly lettuce, and black medic in Felton, MN. High seral forb foliar cover was reduced 10 and 14 MAT from 20% to 2% and 3% in Fargo and from 19% to 2% and 3% in Felton, respectively. The high seral forb species birdfoot violet, white panicled aster, northern bedstraw, Maximillian sunflower, Canada goldenrod, purple meadowrue, and American vetch were reduced at both locations. Low seral forb cover also decreased 10 MAT from 22% to 10% in Fargo and from 12% to 1% in Felton, respectively. By 14 MAT, low seral species in Fargo began to recover and almost doubled to 16%. In Felton, recovery was much slower and included prairie rose, American licorice, and western snowberry. After treatment, high and low seral monocot species increased at both sites due to reduced competition from susceptible species. Porcupine grass increased in Fargo while big bluestem and Indiangrass increased in Felton. AMCP reduced richness, evenness, and diversity at both locations 10 and 14 MAT; therefore, floristic quality declined. Thus, AMCP application in high quality plant communities should be avoided or limited to prevent injury to susceptible, desirable forb species.

Incorporating Trail and Roadway Corridors into a Plant Community Susceptibility Model. Larry W. Lass*, Timothy Prather; University of Idaho, Moscow, ID (012)

Human activities, either deliberate or accidental, introduce and redistribute problem weed species. Our transportation networks allow access to agricultural and natural areas, but also speed the process of invasion by human transport. Incorporating trail and roadway corridors into a plant model recognizes patterns of invasive plant distribution of the transportation network at high risk to invasion. The study area for the project included all of Idaho and adjacent lands in Montana, Nevada, Oregon, Washington and Wyoming with bounding coordinates of -120 to -114 longitude and 37 to 49 latitude. Weed location data were obtained from http://NETMAPS.maps.arcgis.com. Netmaps is a University of Idaho managed site for sharing weed location and site susceptibility data between federal, state and local agencies and land managers. Transportation data were obtained from US TIGER and USFS data for the study area. Transportation data were classified as 1) Highways, 2) County and public roads, 3) Trails and Private roads. A buffer of 30 m and another 31 to 100 m were applied to the 3 transportation classes. A surrogate for biomas was calculated to obtain indications of competing vegetation along roads using Normalized Difference Vegetation Index (NDVI) image for terrestrial sites from NASA data from July 18. 2012.

More than 50% of all known diffuse and spotted knapweed infestations occur within 30 m of a county and public roads. Highways (0 to 30 m) contained less than 12% of the weed populations of all diffuse and spotted knapweed infestations, 10% were along trails and private roads. These calculations demonstrate the importance of county weed programs in order to address a number of weed problems such as those presented by knapweeds. Houndstongue was not as linked to county roads, nor to highways, rather it was associated to private roads and trails suggesting a link to animal movement. Other species like rush skkeletonweed infestations were not strongly associated with roads.

NDVI analysis along county and public roads showed spotted knapweed and houndstongue were taking advantage of areas with 60 to 85% NDVI but other weeds such as diffuse Knapweed and dalmation toadflax were not. Trails and private road NDVI values showed leafy spurge, rush skeletonweed, spotted knapweed and yellow starthistle were associated with the same green vegetation where NDVI ranged between 40 and 70%. Analysis shows NDVI values between 50 and 80% are at risk for invasion along all transportation routes.

Native Forb Response to Aminocyclopyrachlor in the Greenhouse. Travis R. Carter*, Rodney G. Lym; North Dakota State University, Fargo, ND (013)

Aminocyclopyrachlor will effectively control many noxious weeds such as Canada thistle [*Cirsium arvense* (L.) Scop.] and leafy spurge (*Euphorbia esula* L.); however, the efficacy on desirable broadleaf plants is relatively unknown. The susceptibility of 10 prairie forb species to aminocyclopyrachlor was evaluated in the greenhouse. Species were chosen to correlate with a field study of aminocyclopyrachlor and a previous greenhouse experiment using aminopyralid. Plants were either purchased or grown from seed and root from local collections. Aminocyclopyrachlor was applied at 0, 35, 70, and 105 g ha^{-1} with an MSO plus silicone-based NIS blend at 0.25% v v^{-1} when plants reached the growth stage which simulated a spring treatment for weed control. Blueflag iris (*Iris versicolor* L.) and harebell (*Campanula rotundifolia* L.) were relatively tolerant and would likely be unharmed following an application of aminocyclopyrachlor in the field. American licorice (*Glycyrrhiza lepidota* Pursh), prairie rose (*Rosa arkansana* Porter), purple prairie clover (*Dalea purpurea* Vent.), and wild bergamot (*Monarda fistulosa* L.) were moderately susceptible to aminocyclopyrachlor; however, plants might regrow in the field since some survived at high aminocyclopyrachlor application rates. Azure aster [*Symphyotrichum oolentangiense* (Riddell) G.L. Nesom], Canada goldenrod (*Solidago canadensis* L.), great blue lobelia (*Lobelia siphilitica* L.), and purple coneflower (*Echinacea angustifolia* DC.) were susceptible to aminocyclopyrachlor even when applied at 35 g ha^{-1}. Aminocyclopyrachlor effect on plants varied by species and should be considered in a long-term management program.

Herbaceous Plant Response following an Aerial Application of Aminopyralid and Triclopyr to Honey Mesquite. Kirk McDaniel[1], Derek Bailey*[2]; [1]New Mexico State Univ., Lasw Cruces, NM, [2]NMSU, Las Cruces, NM (014)

Paper withdrawn

Translocation of Aminopyralid and Clopyralid in Non-vernalized and Vernalized Rush Skeletonweed (*Chondrilla juncea* L.). Tara Burke*, John F. Spring, Alan J. Raeder, Drew Lyon, Ian C. Burke; Washington State University, Pullman, WA (015)

The growth stage of perennial weeds can have a profound impact on transport of herbicides to above and below ground perennial survival structures and growing points. Rush skeletonweed (*Chondrilla junceae*L.), a problematic weed of rangelands, agricultural fields, and roadsides in the Pacific Northwest, is such a perennial weed. In field research on rush skeletonweed, applications of growth regulating herbicides can be more effective in fall applications compared to spring applications, suggesting that vernalization in rush skeletonweed can have an impact on herbicide absorption and translocation. Therefore, the objectives of this research was to quantify absorption and translocation of clopyralid and aminopryalid to non-vernalized and vernalized rush skeletonweed. Absorbtion of clopyralid and aminopyralid was similar for vernalized and non-vernalized rush skeletonweed plants, although by 72 hours after treatment more clopyralid than aminopyralid is absorbed (90% and 80% for vernalized plants and 93% and 83% for non-vernalized plants, respectively). Translocation was affected by herbicide and vernalization. For clopyralid, translocation to the roots (and the rhizome, the perennial survival structure) was decreased following vernalization (12% of applied material for non-vernalized plants and 3.2% of applied material for vernalized plants), while the reverse is true for aminopyralid - 1.8% of applied material for non-vernalized plants and 4.4% of applied material for vernalized plants. Absorption and translocation of clopyralid and aminopyralid were affected by vernalization, and more clopyralid was absorbed than aminopyralid. Greater accumulation of aminopyralid in the roots and rhizome structure after vernalization require further investigation.

Indaziflam: Potential New Herbicide to Control Invasive Winter Annual Grasses. Derek J. Sebastian*, Charles T. Hicks, Scott J. Nissen; Colorado State University, Fort Collins, CO (016)

Managing invasive winter annual grasses on non-crop and rangeland remains a constant challenge throughout many regions of the US. During the winter and early spring months, these species exploit moisture and nutrients before native plant communities break dormancy in the spring. This results in dense, monotypic stands of winter annual grasses invading roadsides, abandoned crop fields, overgrazed grasslands, and open space properties. Currently, there are limited management options for controlling winter annual grasses that work consistently, provide multiple years of control, and do not injure desirable plant communities. Imazapic has been one of the most-widely used herbicides on rangeland, but this herbicide lacks consistency beyond the year of application and can cause injury to perennial grasses. Indaziflam, a new herbicide mode of action for rangeland weed management, has provided long-term residual winter annual grass control in several field experiments. A greenhouse study was conducted to compare indaziflam and imazapic pre-emergence control of downy brome (*Bromus tectorum* L.), feral rye (*Secale cereale* L.), jointed goatgrass (*Aegilops cylindrical* L.), Japanese brome (*Bromus japonicus* Thunb.), medusahead (*Taeniatherum caput-medusae* [L.] Nevski), and ventenata (*Ventenata dubia* (Leers) Coss). For each herbicide, seven rates were used to develop dose-response curves for each species. Log-logistic regression was conducted to determine GR_{50} values. Indaziflam provided superior winter annual grass control across all species, compared to imazapic. The GR_{50} values for imazapic were on average 15 times greater than indaziflam. Jointed goatgrass was the most difficult winter annual grass to control for both herbicides. This research provides evidence of a potential new tool and mode of action for land managers to control the major invasive winter annual grasses on US rangeland.

Evaluating the use of Thresholds Concepts for Improving Habitat through Cheatgrass Management. Clay W. Wood*[1], Brian A. Mealor[2]; [1]University of Wyoming, Laramie, WY, [2]University of Wyoming, Sheridan, WY (017)

Invasive species impact the ecological and economic functions of ecosystems. Downy brome is an invasive annual grass widely distributed throughout most of the western United States. Downy brome produces fine fuels which can increase fire frequency and alter vegetation composition and structure. Although downy brome may be used as forage by livestock and wildlife, it may not be preferred. We hypothesize a direct, predictable relationship between pre-treatment vegetation condition and post-treatment forage response that may be defined at lower levels of downy brome by minimal post-treatment grass increase and in more severe infestations by more pronounced increases in forage post-treatment. By identifying these treatment-response thresholds, we hope to aid managers in prioritizing where treatments will provide the greatest benefit. In 2015, we sampled locations representing a gradient of downy brome to perennial grass biomass and canopy cover ratios prior to herbicide application across multiple sites. We employed four different sampling methods to determine various ratios of downy brome to perennial grass using biomass and cover. Comparisons will be made among sampling methods to determine which method best predicts post-treatment forage response. We aerially applied two imazapic formulations during fall 2015. Post-treatment data will be collected in 2016 to evaluate the response of downy brome and associated vegetation following herbicide application. With a better understanding of downy brome and perennial grass response following herbicide treatment at different infestation thresholds we aim to provide information that land managers can use to refine landscape-scale management strategies.

Buckhorn Plantain Control in Irrigated Pasture. Ralph E. Whitesides*[1], Allan Sulser[2], Corey Ransom[1]; [1]Utah State University, Logan, UT, [2]Utah State University, Heber City, UT (018)

Buckhorn plantain (*Plantago lanceolata* L.) has been reported in 20 of Utah's 29 counties. This is a weed with increasing significance in Utah pastures and cropland, including alfalfa. Buckhorn plantain competes for soil nutrients, water, and light and can out-compete desirable species. Animals will rarely eat it when grazing, and when made into hay it turns black and discolors bales. This plant is widespread in high mountain pastures and dominates the ecosystem once established. Experiments were conducted during 2011, 2012 and 2014 in a 12-acre irrigated pasture in Wasatch County, Utah (elevation 5600 ft) that was heavily infested with buckhorn plantain. Herbicide applications in 2011 were made using a trailer-mounted, boom-less sprayer pulled by an ATV and delivering 16 GPA. In 2012 and 2014 plot treatments were made with a CO_2 backpack sprayer delivering 18 GPA at 35 psi. Applications in 2011 and 2012 were made in May when buckhorn plantain plants were vegetative and in the early rosette stage. In 2014, herbicides were applied in July or in October, when buckhorn plantain was mature and had produced a seed head. Triclopyr, chlorsulfuron, metsulfuron, 2,4-D amine, and 2,4-D amine + dicamba were herbicides evaluated in 2011 and 2012. Treatments with chlorsulfuon and metsulfuron caused some short-term chlorosis on grasses in 2012. Visual ratings and stand counts showed 2,4-D amine (Weedar 64 at 4 pt/A) and metsulfuron (Escort XP at 0.5 oz/a + NIS 0.25% v/v) to be most effective in 2011. Control was 87 and 90% respectively 68 days after treatment (DAT). In 2012, evaluations made 59 DAT showed metsulfuron (Escort XP 1.0 oz/a + NIS 0.25% v/v) and metsulfuron plus 2,4-D amine (Escort XP 1.0 oz/a + 2,4-D as Weedar 64 4 pt/a) or metsulfuron plus dicamba (Escort XP 1.0 oz/a + dicamba at 8 oz/a) were most effective and control was 85%, 84% and 82% respectively. Significant reductions in weed populations were not always observed when evaluations were made 35 or 36 DAT regardless of the year (2011 or 2012). The density of buckhorn plantain in treated plots increased when evaluations were made 92 or 99 DAT, indicating a decline in control. Because herbicide treatments in 2011 and 2012 did not provide season-long control from spring applications, treatments in 2014 changed herbicide timing to summer and fall and added picloram to the herbicides being evaluated. Plot evaluations in 2015 showed that fall application (October 16, 2014) of picloram (Tordon 22K 2 pts/A) or picloram + 2,4-D (Grazon P+D 4 pts/A) gave 100% control of buckhorn plantain 240 DAT (8 months) and increased grass density by 75% compared to pre-treatment evaluations. No significant visual symptoms were observed on the pasture grasses in these studies from any treatment. Buckhorn plantain populations were reduced most significantly by picloram and picloram combinations with 2,4-D when application was made in late fall.

Solar Tenting as a Tool for Managing Invasive Weeds - A Research Update. James J. Stapleton*[1], Steve B. Orloff[2], Nicole O. Stevens[2]; [1]University of California, Parlier, CA, [2]University of California, Yreka, CA (019)

Field experiments were conducted during summer months in Yreka and Scott Valley, Siskiyou County, California, to test effects of seed incubation in solar tents on germination. In 2015, seeds of dyers woad (*Isatis tinctorius*) and/or intact capitula of Taurian thistle (*Onopordum tauricum*) were placed within black plastic trash bags. Tap water was added to the bags to immerse the seeds, and the bags were arranged within solar tents. Solar tent construction used locally-available materials, similar to those which could be scavenged in many California ecoregions. Control seed aliquots were bagged in the same manner and left on a laboratory bench at ambient room temperature (68 to 78 F). At the Yreka site, seeds were treated from 31 July to 09 September. Within solar tents, daily high temperatures in the water reservoirs containing seeds ranged from 140-170 F. Following the treatment periods, nontreated control seeds of *I.*

tinctorius from the Yreka and Scott Valley sites were 100% germinated within 30 days, while those from solar tents were completely nongerminable. Although germination of *O. tauricum* control seeds was low (<20%) and nearly all seeds were colonized by fungi, preliminary results showed that no seeds from the solar tent treatment germinated within the 30 day assay period. In sufficiently warm climatic areas and weather conditions of California and elsewhere, similar tents, which employ passive solar energy, can provide a useful alternative for inactivating weed propagative materials. Uses may include on-site destruction of quarantined, propagative materials following regulatory roguing in remote locations, or routine roguing of limited scale areas to remove invasive weeds.

Phenology of the Biological Control Agent of Dalmatian Toadflax, *Mecinus janthiniformis* (Curculionidae: Coleoptera), in Utah. Samantha A. Willden*, Edward W. Evans; Utah State University, Logan, UT (020)

Noxious weeds threaten biodiversity and ecosystem function in range and wild lands by outcompeting and ultimately displacing desirable vegetation. One option for the control of such weeds is biological control via insect herbivory. Insects have been introduced as natural biocontrol agents of many pervasive weeds in North America but there is limited understanding of their phenology or physiological timing of life stages. Presented is a study based on the phenology of *Mecinus janthiniformis* attack on *Linaria dalmatica* in Utah. Stem census and sexing data were collected for two consecutive years on the host plant in Tooele, Utah to compare general population and sex specific seasonality using simple calendar dating and degree-day modeling. Our observations of *M. janthiniformis* populations show that phenological patterns were consistent at sites between years, and that male and female phenologies differ in that males appear earlier on the host than females, an example of insect protandry. Although males reached peak abundance slightly earlier than females in one year and considerably earlier in the second, overall patterns of phenology between the sexes are similar when assessed using degree-day accumulation. Thus degree-day modeling, as opposed to calendar dating, proves to be the more reliable method for predicting *M. janthiniformis* phenology. The primary application of this study is the development of degree-day models that can be used to predict weevil phenology; this knowledge is useful for guiding practitioners of biocontrol in determining when to visit *L. dalmatica* populations to assess agent establishment and to collect insects for future distribution.

Project 2. Weeds of Horticultural Crops

Investigating the Potential of Hay Mulch and AMF Inoculant for Small-Scale Organic Vegetable Crop Production. Greta G. Gramig*[1], Patrick Carr[2]; [1]North Dakota State University, Fargo, ND, [2]Montana State University, Moccasin, MT (021)

During 2015, field experiments were established to investigate impacts of hay mulch and arbuscular mycorrhizal fungi (AMF) inoculant on onion, table beet, winter squash, and sugar snap pea yield in an organic vegetable production system. These experiments were located in Dickinson and Absaraka, ND. The experimental design was a randomized complete block in a split plot arrangement with mulch type (hay mulch or bare soil) as the main plot factor and factorial combinations of crop species x AMF inoculant as the subplot plot factor. Plots measured 2.4 x 3.0 m. All crops except squash were planted in three 3.0 m long rows centered within the plots. Squash was planted in one centered 3.0 m long row. 'Dakota Tears' organic onion seeds (*Allium cepa*) were sown in the greenhouse in February and planted as seedlings in the field in early May at 10 plants m^{-2}. Table beet (*Beta vulgaris*), winter squash (*Cucurbita maxima*), and sugar snap pea (*Pisum sativum*) were directly sown in mid-May (beet and pea) or early June (squash). Peas were sown at a rate of 48 seeds m^{-2}. The sugar snap pea was a dwarf variety that doesn't require staking. Beets were sown at a rate of 24 seeds m^{-2} and thinned to 16 plants m^{-2} at 4 to 6 leaves. Squash was seeded at 1.5 seeds m^{-2} and plants were thinned to 0.5 plants m^{-2} at 4 to 6 leaves. 'Mycogrow' AMF inoculant (Fungi Perfecti, LLC, Olympia, WA) was applied in a water solution at a rate of 7.4 g L^{-1} to half the plots after planting crops. This inoculant contained AMF species *Glomus intraradices*, *Glomus mosseae*, *Glomus aggregatum*, and *Glomus etunicatum.* Hay mulch from square bales was applied after crop emergence in a layer that was approximately 15 cm deep. Weeds were removed from all plots on a timely basis, so yield differences among treatments were due to factors other than crop-weed competition. Time required for weed removal was recorded. Neither site was irrigated but rainfall was fairly frequent at both sites. Both sites were fertilized with chicken (Absaraka) or cow (Dickinson) manure to prior to planting. Soil from each plot was tested for N-P-K and although variation across plots was great, nutrients were present in adequate amounts for vegetable production. Peas were harvested every two to three days during July. Beets were harvested mid-August. Onions were harvested in mid-September and squash were harvested in mid-October. The hay mulch almost completely suppressed weed emergence whereas weed pressure in the bare plots was considerable. Bare plots required substantially more weeding time than the mulched plots. Per plant pea yield on a mass basis did not differ among treatments, but there were fewer pea pods per plant for plots treated with AMF at the Absaraka site only. Per plant beet yield was greater at the Absaraka site than at the Dickinson site. Across sites, per plant beet yield was greater in hay mulched plots than in bare plots, but only in the absence of AMF. Total onion yield, mass per onion, and number of onions per plot were greater for mulched plots than for bare plots. Mass per onion was greater at Absaraka than at Dickinson, but only for bare plots. Squash yield was greater in mulched plots than bare plots, and greater at Absaraka than at Dickinson. Other than a reduction in pea pod number at the Absaraka site, AMF inoculant had no impact on crop yield. Crop yield differences associated with mulch were mostly likely due to superior water retention by the hay mulch compared to bare soil. Yield differences associated with site were probably also due to differences in moisture, as Dickinson received somewhat less precipitation than Absaraka (219 vs. 383 mm from May to August). Also, though the tested effect was marginally insignificant ($p=0.0595$), mulched plots tended to have greater numbers of onions than bare plots at both sites. Both sites were affected by fusarium basal rot (*Fusarium oxysporum)*, a soil-borne fungal pathogen and numerous onions died and rotted prior to harvest. This trend suggests that the mulch may have prevented the spread of the disease by blocking the splashing action of water during precipitation events. This study will be repeated in 2016 and 2017 to assess cumulative effects of the treatments on soil quality measures, as well as crop yield and weed suppression.

Mulch and Biochar Impacts on Organic Strawberry Establishment. Samantha K. Hogstad*[1], Greta G. Gramig[1], Patrick Carr[2]; [1]North Dakota State University, Fargo, ND, [2]Montana State University, Moccasin, MT (022)

Strawberries grown in organic production systems are commonly mulched with hay/straw or plastic. Although hay/straw mulches add organic matter to the soil, these materials can be unstable in windy conditions, harbor weed seeds, and encourage pests such as slugs. Plastic mulches efficiently suppress weeds; however, plastic does not biodegrade, thus presenting a disposal problem. Plastic mulches are also unsuitable for perennial matted-row strawberry production, which is most commonly practiced in the north central U.S. Effective weed management is crucial for perennial strawberry production and the common mulching materials pose weaknesses; therefore, introducing novel mulch materials would benefit producers. Diseases also pose a threat to strawberry production. Biochar has been previously shown to increase resistance to some diseases and improve growth and yield of strawberry plants. Field trials were conducted at the NDSU Horticulture Research Farm in Absaraka, ND and at the Dickinson Research Extension Center in Dickinson, ND, to examine the ability of three organic mulch materials and pine-derived biochar to aid in perennial strawberry production. In early June 2015, Cavendish variety bare root strawberries were transplanted into prepared beds at both sites. The experimental design was a 2 (biochar vs. no biochar) x 4 (alfalfa hay, paper, hemp hurd, or no mulch) factorial arranged in a randomized complete block. To establish a perennial matted row system, flowers were removed to encourage runner production and vegetative growth. Weed biomass, flower production, leaf number, runner production, and soil water content were measured throughout the growing season. Because weeds were removed, crop-weed competition did not occur, and therefore differences in plant responses associated with mulch treatments were due to other factors. All mulches suppressed weeds equally well compared to bare soil. Hay mulch was associated with fewer strawberry leaves compared to bare soil and paper or hemp mulch. Strawberry plants mulched with paper or hemp produced greater numbers of runners than plants grown in bare soil or mulched with hay. At Absaraka, hay-mulched strawberry plants produced fewer flowers than plants grown in bare soil or with paper or hemp mulch. At Dickinson, strawberry plants grown with hay mulch and in bare soil produced fewer flowers than plants grown with paper or hemp mulch. Biochar was associated with decreased flower counts at Dickinson, but did not impact other measures of strawberry growth. Soil temperature and volumetric water content did not differ among any treatments, indicating that mulch and biochar treatments indirectly impacted strawberry growth via some other factor.

Irrigation and Nitrogen Fertilization Effects on Weed Encroachment and Persistence in Established Turf. Kyle Frandsen*, Don Morishita, Samara L. Arthur; University of Idaho, Kimberly, ID (023)

White clover and common dandelion are some of the most common weeds in turf. Herbicides, such as dicamba or triclopyr, can be successful in controlling white clover and common dandelion if applied at correct timings and rates. However, with increasing societal concerns about the use of pesticides there is a growing movement to find alternative methods to control weeds in landscapes. Little scientific research exists which has specifically evaluated nitrogen fertility and irrigation management practices as an alternative method to control common weeds in turfgrass. Research was conducted in 2014 and 2015 to evaluate white clover, common dandelion, and other common turf weed species invasion and management under varying irrigation and nitrogen fertility regimes. Irrigation treatments were established by watering to meet 70, 100 and 130% of evapotranspiration for turf. Nitrogen rates used were 0, 2.4, 4.9 and 7.3 g of nitrogen per m^2 applied 4 times throughout each growing season for a total of 0, 9.6, 19.6 and 29.2 g of nitrogen per m^2 per year respectively. The experimental design was a split block randomized complete block with three replications. Irrigation treatment was the main plot and nitrogen rate was the sub-plot. Nitrogen fertility treatment influenced clover and common dandelion populations throughout the growing season. White clover densities were the highest for the 0 and 2.4 g nitrogen treatments while clover densities were lowest for the 7.3 g nitrogen treatments. Treatments receiving even the lowest nitrogen fertilizer rate showed a reduction in common dandelion population when compared to unfertilized treatments. Differences in both the color and quality of the turf were observed between fertility treatments. In 2015 each sequentially higher fertility rate resulted in increased turf color and quality. Generally, irrigation treatment did not have a significant effect on clover or dandelion encroachment and/or persistence. Although the correlation between turf irrigation rates and turf color/quality ratings was largely not statistically relevant, numerical trends strongly suggest that the color and quality of the turf was reduced when irrigated at a 70% ET rate.

Herbicide Effects on Kurapia (*Lippia nodiflora*). Jerry Che, Kai Umeda*, Worku Burayu; University of Arizona, Phoenix, AZ (024)

Kurapia (*Lippia nodiflora*) is a non-invasive groundcover cultivar from Japan. As a groundcover, it has a dense canopy and a deep root system to enhance drought tolerance and prevent soil erosion. The purpose of these experiments was to examine the immediate effects on kurapia of twelve postemergence and eight preemergence herbicides. Experimental results will indicate which herbicides could potentially be used on kurapia to safely provide weed control. Results showed that three preemergence and two postemergence herbicides were safe. After 12 weeks of data collections, pronamide, isoxaben, and prodiamine were the least injurious preemergence herbicides with injury ranging from 20 - 25%. Halosulfuron and sulfosulfuron appeared to be the safest postemergence herbicides with both showing below 20% injury after 2 weeks of applications. Sulfentrazone caused significant damage to kurapia. Many of the postemergence herbicides showed progressive injury and injury increased after a week. Fluroxypyr and the premix combination product 2,4-D + MCPP + dicamba caused 43% injury and 42% injury, respectively, after the first week; however, after the second week, injury by fluroxypyr increased to 76% and 2,4-D + MCPP + dicamba increased to 78% injury. Kurapia treated with quinclorac and the premix combination product iodosulfuron + dicamba + thiencarbazone showed recovery from stunted leaf growth symptoms but continued to exhibit burning symptoms; therefore, their injury worsened. Kurapia was slightly injured by some herbicides but with the promise of pronamide, isoxaben, prodiamine, halosulfuron, and sulfosulfuron offering better safety.

Weed Control in Table Beet Seed Production in the Pacific Northwest. Carl R. Libbey*, Timothy W. Miller; Washington State University, Mount Vernon, WA (025)

Herbicide combinations were evaluated for weed control in table beet seed production in northwestern Washington. Trials were established in commercially grown red beet seed fields in 2014 and 2015, and in yellow beet seed in 2014. Vernalized beet seedling and steckling (bulbs) were transplanted in May, 2014 and April, 2015, and herbicides were applied immediately after transplanting followed three weeks later with postemergence treatments. The 2014 red beet treatments did not reduce seedling survival at 2 WAT and 3 WAT, except flumioxazin reduced seedling number at 2 WAT. Slight beet leaf injury was visible at 3 WAT with flumioxazin, metribuzin, and sulfentrazone. Beet steckling leaf emergence was delayed with flumioxazin, sulfentrazone, and EPTC at 2 WAT. Postemergence applications of ethofumesate to bolted red beet plants resulted in flower stem injury, with female seed lines more sensitive than males and female seedlings far more sensitive than female stecklings. In the yellow beet trial there was no significant difference in seedling survival rates at 4 WAT or in steckling emergence at 2 WAT. Ethofumesate applied to bolted yellow beet seedlings or stecklings did not cause visual injury. There was no difference in red or yellow beet seedling or steckling seed yield, although yield per plant was greater with stecklings than seedlings. In 2015, trials were in two red beet steckling fields and one red beet seedling field. Most treatments caused less than 6% early season injury, including flumioxazin, metribuzin, sulfentrazone, and EPTC. However dimethenamid-p fb (dimethenamid-p + ethofumesate + MSO) resulted in an average 16% injury across all seed lines and sites, contrasted with an average of 3% with s-metolachlor fb (s-metolachlor + ethofumesate + MSO). By July the only treatment still causing visible injury (32%) was s-metolachlor fb (asulam + clopyralid + triflusulfuron + MSO). There was no significant difference in seedling or steckling density due to treatments. All treatments resulted in weed control greater than 92% which lasted through mid-July. Weed control with s-metolachlor fb (asulam + clopyralid + triflusulfuron + MSO) was significantly lower in July (80%), probably due to greater crop injury that limited competition with weeds.

Timing of Linuron Treatments in Potato Production. Andy Robinson*; North Dakota State University /University of Minnesota, Fargo, ND (026)

Abstract not available

Breaking Bindweed: A Summary of Three Years of Research in CA Processing Tomatoes. Lynn M. Sosnoskie*, Bradley D. Hanson; University of California, Davis, CA (027)

Processing tomato production in California has changed, dramatically, over the last half-century. Improved cultivars, conversion from seeded to transplanted production, commercialization of the mechanical harvester, and the steady adoption of drip irrigation have helped to expand the size and economic value of the industry. In 2013, California led the nation in the production of processing tomatoes in terms of hectares planted and harvested (105,000 ha), total yield (10 million metric tons), and total value of production ($918 million). The adoption of drip irrigation also reduced in-crop weed densities (small-seeded annual species) and the need for subsequent cultivation. One weed that has been less impacted by the swith to drip systems is field bindweed (*Convovulous arvensis*), a deep-rooted and drought-tolerant perennial that can be difficult to control once it has become established.

Field studies were conducted in 2013 and 2014 to evaluate the efficacy of currently registered PPI, PRE and POST herbicides for field bindweed management in processing tomatoes in California. Results show that bindweed cover was reduced >50% in early-planted tomatoes, relative to the control (0 to 30% cover up to 6 WAT), when using trifluralin, alone, or in combination with rimsulfuron, *S*-metolachlor or sulfentrazone (0 to 10% cover up to 6 WAT). Similar trends were observed with respect to field bindweed density. Pre-plant applications of glyphosate to emerged bindweed in late-planted tomatoes, coupled with PPI/PRE herbicide applications, reduced weed cover (1 to 13% up to 6 WAT) by more than half when compared to plots treated with residual herbicides, alone (1 to 43% up to 6 WAT). Similar trends were also observed for weed density in late-planted tomatoes. Herbicide tank-mixes and sequential herbicide treatments can broaden the spectrum of weeds controlled in processing tomato, including field bindweed emerging from seed. However, the most simple and cost-effective approach for managing field bindweed emerging from perennial structures may be to combine glyphosate treatments before final bed preparation and later transplanting dates in tomato fields with heavy field bindweed infestations.

Additional studies were conducted in 2015 to evaluate the effects of irrigation strategy (drip, furrow and sprinkler) on herbicide activation and field bindweed suppression. The soil-applied herbicides registered for use in processing tomato vary significantly with respect to their solubility in water, adsorption and moisture requirements for activation. These factors, in combination with local edaphic/environmental conditions at and following the time of application, affect herbicide performance. Suppression of field bindweed by *S*-metolachlor, rimsulfuron, and sulfentrazone was greatest in the sprinkler irrigated plots 3 to 4 weeks after treatment. At 3 to 4 weeks after treatment, weed cover in the *S*-metolachlor-, rimsulfuron-, and sulfentrazone-treated plots ranged from 50 to 80% in the furrow- and drip-irrigated systems; in the sprinkler-irrigated plots, field bindweed cover did not exceed ~40% in any of the herbicide treatments. Although drip-irrigation can reduce labor costs, prevent some disease development, improve water use efficiency, and aid in weed control efforts by reducing surface wetting and, therefore, weed seed germination, it is not effective at activating many of our residual herbicides. Growers with significant field bindweed problems should be mindful of how their irrigation protocols may affect herbicide performance.

The successful control of deep-rooted perennials, such as field bindweed, is dependent upon herbicides reaching latent root and shoot buds. The majority of root/rhizome biomass for field bindweed is located within the top 2 feet of the soil profile, although some vertical roots can reach depths of more than 10 feet. Conversely, Treflan and other residual herbicides registered for use in processing tomatoes are usually incorporated into the top 2 to 3 inches of the soil profile. Because of their shallow placement, these herbicides may not suppress bindweed vines that are emerging from deeply buried rhizomes. In 2015, we undertook a similar study in processing tomatoes. Specifically, our research was focused on describing how sub-surface applications of trifluralin interacted with surface applied herbicides (trifluralin, *S*-metolachlor, and sulfentrazone with respect to field bindweed control. Results from our study show that broadcast (trifluralin to the entire width of the bed) sub-surface herbicide applications can significantly reduce field bindweed cover relative to the untreated check (no sub-surface trifluralin) or banded (trifluralin applied, sub-surface, only to the outermost 6 inches of the bed) treatments. When averaged over PPI and PRE herbicides, field bindweed cover in the broadcast treatment ranged from 7 to 36%, whereas bindweed cover in the banded and the trifluralin-free (sub-surface) plots ranged from 10 to 50%. An evaluation of the data achieved from these trials suggests that we do have herbicides that are able to supress field bindweed in processing tomato systems, however, the efficacy of these products are likely to vary with respect to both placement and activation strategy. Continuing research is being conducted to evaluate how the type and timing of herbicide applications affect in-crop perennial bindweed control.

Evaluating Postemergence-directed Applications of Flumioxazin in Chile Pepper. Brian J. Schutte*, Edward Morris; New Mexico State University, Las Cruces, NM (028)

The chemical control catalogue for chile pepper is lacking in post-direct herbicides that are applied near the time of crop thinning (9 to 10 weeks after seeding). Previous studies determined that many weeds in chile pepper can be controlled with flumioxazin; however, this herbicide is not registered for use in chile peppers in New Mexico. The objective of this study was to evaluate post-direct, hooded applications of flumioxazin for injury on chile pepper. To accomplish this objective, field studies were conducted at two university research farms: NMSU Leyendecker Plant Science Center in Las Cruces, NM; and NMSU Los Lunas Agricultural Science Center. Soil at the Las Cruces site was a silty-clay, and soil at the Los Lunas study was a sandy-clay loam. At both sites, chile peppers were grown according to irrigation, soil and pest management practices typical for the region. Treatments were as follows: (1) flumioxazin (0.107 kg ai ha^{-1}) at four weeks after crop thinning, (2) carfentrazone (0.035 kg ai ha^{-1}) at 4 weeks after crop thinning, (3) flumioxazin (0.07 kg ai ha^{-1}) at 4 and 6 weeks after crop thinning, (4) carfentrazone (0.035 kg ai ha^{-1}) at 4 and 6 weeks after crop thinning, and (5) unsprayed control. Carfentrazone is registered for use in chile pepper and features the same mechanism of action as flumioxazin (Protoporphyrinogen Oxidase [PPO] Inhibitors). All plots sprayed with flumioxazin and carfentrazone showed characteristic PPO inhibitor damage (speckling followed by chlorosis then necrosis) to some lower leaves on chile pepper plants. At Las Cruces, chile pepper yield was not influenced by herbicide treatment. At Los Lunas, flumioxazin reduced yield of specific chile pepper cultivars (NM 6-4, Paprika, Sandia) compared to unsprayed controls; however, yield reductions were not observed for the carfentrazone treatments. The results of the first year of this study suggest that a registration for post-direct, hooded applications of flumioxazin in chile pepper would need to be conditioned by soil type. It is expected that the study conclusions will be strengthened and clarified with second year data.

Response of Walnuts to Simulated Drift of Rice Herbicides. Mariano F. Galla*, Kassim Al-Khatib, Bradley D. Hanson; University of California, Davis, CA (029)

English walnut is one of the top commodities grown in California and its importance in the Sacramento Valley has been increasing in the last decade. Growers, pest control advisors and county agricultural commissioners are concerned with spotting observed on young walnut leaves that appear to be related to drift of rice herbicides. The majority of rice herbicide applications are made by air between the end of May and early July. This time frame coincides with a period of rapid growth for walnut trees and as well as flower bud initiation for the next year. Therefore it is possible that herbicide drift at this time may impact walnut growth and future yield. Experiments were conducted in Davis, CA to evaluate walnut response to simulated drift rates of several rice herbicides. Young walnut trees were treated with bispyribac, bensulfuron and propanil at 0.5%, 1%, 3% and 10% of the use rate (44.8, 70.2, and 6725.1 g ai/ha for bispyribac, bensulfuron and propanil, respectively). All herbicides caused symptoms to young walnut leaves and shoots. The severity of symptoms peaked 28 days after treatment. In a separate study, walnut trees were treated with four sequential applications of two rates (0.5% and 3% of the use rate) of bispyribac on a weekly interval. Bispyribac significantly delayed the growth of new leaves in young shoots. Although recovery was noted at 28 DAT, chlorotic spotting and distorted shoot growth caused by ALS inhibitor herbicides was still present four months after treatment application in both experiments.

Susceptibility of Italian Ryegrass to Orchard Herbicides in California. Caio Brunharo*, Bradley D. Hanson; University of California, Davis, CA (030)

Glyphosate-resistant populations of Italian ryegrass are widely spread in California. Alternative chemical management has become crucial for controlling this species in POST applications. The response of susceptible (SLB), glyphosate-resistant (GR10) and a suspected paraquat-resistant (PRHC) Italian ryegrass population to POST herbicides was evaluated using greenhouse dose-response experiments. The field rate of clethodim (272 g ha^{-1}), fluazifop (210 g ha^{-1}), glyphosate (1260 g a.e.ha^{-1}), mesosulfuron (15 g ha^{-1}), paraquat (840 g ha^{-1}), pyroxsulam (14.8 g ha^{-1}), rimsulfuron (210 g ha^{-1}) and sethoxydim (157.5 g ha^{-1}) were each applied at a range of rates up to eight times their field rate, in a completely randomized design with four replications per treatment. Treatments were applied using a spray chamber calibrated to deliver 200 L ha^{-1}. Aboveground biomass was collected 28 DAT and dried for analysis of resistance factors (RF = GR_{50R}/GR_{50s}). GR10 is highly resistant to fluazifop (RF=72) and glyphosate (RF=36) and moderately resistant to clethodim (RF=2.5) and mesosulfuron (RF=4). PRHC is highly resistant to sethoxydim (RF=2416), pyroxsulam (RF=24), glyphosate (RF=15) and clethodim (RF=9), and moderately resistant to mesosulfuron (RF=2) and rimsulfuron (RF=3). The lowest rate of paraquat was effective on S and GR10; therefore, it was not possible to obtain their GR_{50}. The GR_{50} for PRHC was 1364 g ha^{-1} for paraquat. In this research, GR10 was resistant to three herbicide modes of action and PRHC to four, which emphasizes the need for orchard weed managers to implement more diverse and integrated strategies to control Italian ryegrass in CA orchard crops.

Cross-Resistance of *Conyza bonariensis* and *Conyza canadensis* Biotypes Resistant to Glyphosate and Glyphosate-Paraquat. Marcelo L. Moretti[1], Lucas K. Bobadilla[2], Bradley D. Hanson*[1]; [1]University of California, Davis, CA, [2]University of Sao Paulo, Piracicaba, Brazil (031)

Conyza bonariensis and *C. Canadensis* populations that are glyphosate-resistant (GR) and glyphosate-paraquat-resistant (GPR) have been documented in California. The objective of this work was to determine if these biotypes are also resistant to other herbicide modes of action (MOA). Biotypes selected for this study included GPR, GR, and glyphosate-paraquat-susceptible (GPS) *C. bonariensis* and *C. canadensis*. A series of greenhouse dose response experiments were conducted to simultaneously evaluate the response of all six biotypes during spring and summer of 2015. Plants were treated at 5- to 8-leaf stage using a single nozzle cabinet sprayer calibrated to deliver 200 L ha^{-1}. Herbicide MOA and active ingredients tested included: WSSA group 2 (rimsulfuron), group 4 (2,4-D and dicamba), group 5 (hexazinone), group 10 (glufosinate), group 14 (flumioxazin and saflufenacil), group 22 (diquat), and group 27 (mesotrione). Each herbicide was tested at nine different rates including non-treated control, with four replicates per biotype by treatment combination. All experiments were repeated. Aboveground dry biomass was evaluated 21 days after application. Data were analyzed using log-logistic regression, and the rate causing 50% growth reduction (GR_{50}) was used to compare sensitivity among biotypes. All biotypes responded similarly to 2,4-D, glufosinate, flumioxazin, saflufenacil, and mesotrione. The GPS biotypes were slightly more tolerant to rimsulfuron than GR and GPR. Differences in sensitivity to dicamba and hexazinone were observed among biotypes, but these differences were not associated resistance to glyphosate or paraquat. In *C. bonariensis*, the GR_{50} of the GPR biotype was 0.20 kg ha^{-1} of diquat or 6-fold greater than GPS, and in GPR *C. canadensis*, the GR_{50} was 0.27 kg ha^{-1} of diquat or 14.5-fold greater than the GPS. The GR biotypes were equally or more sensitive to diquat than their respective GPS biotypes. The GPR biotypes of both *Conyza* sp. were resistant to diquat, another Group 22 herbicide; however the GPR and GR biotypes did not appear to have cross resistance to the other MOA herbicides tested in this study.

Project 3. Weeds of Agronomic Crops

Investigating Glyphosate Resistance Mechanisms in California Junglerice Populations. Sarah Morran*, Brad Hanson; The University of California, Davis, CA (032)

Herbicide-resistant weed species pose difficult problems for weed management in orchard and vineyard specialty cropping systems in California. The evolution of glyphosate-resistant (GR) junglerice biotypes across the Central Valley agricultural area further challenge growers in this region. Previous field research suggested different levels of glyphosate resistance among populations. F_4 inbred lines were developed from the field populations to investigate the mechanism(s) of resistance in this species. The sequencing of a region of the 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) gene revealed target site mutations were present at the Proline-106 codon. Three single nucleotide changes leading to amino acid substitutions at Proline 106 were identified including Pro106Leu, Pro106Thr and Pro106Ser. Interestingly, lines containing the same PRO106Leu substitution in the EPSPS enzyme showed different glyphosate resistance profiles yet accumulated shikimic acid at similar levels when treated with glyphosate. The shikimate accumulation in these Pro106Leu lines was not significantly different at ½X the field rate of glyphosate, however was significantly different at the 1X field rate (870 g.ae.ha^{-1}). These results suggest the possible interaction of multiple resistance mechanisms contributing to glyphosate resistance in junglerice from California.

Survival and Fecundity of Glyphosate-Resistant Kochia with Variable EPSPS Gene Copies in Response to Glyphosate Selection. Charlemagne A. Lim*[1], Prashant Jha[1], Vipan Kumar[1], Shane Leland[2], Anjani J[1]; [1]Montana State University, Huntley, MT, [2]Montana State University-Bozeman, Huntley, MT (033)

Field experiments were conducted at the MSU SARC, Huntley, MT to determine the survival and fecundity of glyphosate-resistant (GR) kochia with variable *EPSPS* gene copies in the presence of glyphosate. Seeds from a segregating GR kochia population (2014) from MT were used. Experiments were conducted in a randomized complete block design with a factorial arrangement of treatments with six replications, and repeated. Kochia seedlings with known *EPSPS* copy numbers (1 = susceptible, 2 to 4 = low resistance, 5 to 6 = moderate resistance; 8 to 15 *EPSPS* copies = high resistance) were transplanted in the field. Glyphosate rates included: 0; 870; 870 followed by (-) 870 (1,740 g ha^{-1}); 1,265-949 (2,214 g ha^{-1}); 1,265-949-870 (3,084 g ha^{-1}); and 1,265-949-870-870 (3,954 g ha^{-1} total). Sequential treatments were applied 10 d apart, simulating POST applications in GR sugar beet. ED_{90} values (dose needed for 90% control) were 1,841 and 1,965 g ha^{-1} for GR kochia with 2 to 4 and 5 to 6 *EPSPS* copies, respectively, compared with >19,773 g ha^{-1} for GR plants with >7 *EPSPS* copies. No differences in the time of flowering, seed set, pollen viability, seed viability, and 1000-seed weight were observed. However, GR kochia with 2 to 4 and 5 to 6 *EPSPS* copies failed to produce seed at 1,265-949 g ha^{-1} or higher rates of glyphosate applied sequentially. GR kochia with 8 to 15 *EPSPS* copies need to be hand-removed before seed set in the absence of alternative, effective herbicides in GR sugar beet.

Physiological Studies of Auxin Herbicide Resistance in *Amaranthus tuberculatus* and *Sonchus arvensis*. Marcelo de Figueiredo*[1], Anita Kuepper[1], Kallie C. Kessler[1], Scott J. Nissen[1], Christopher Preston[2], Philip Westra[1], Greg R. Kruger[3], Todd Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]The University of Adelaide, Adelaide, Australia, [3]University of Nebraska, Lincoln, NE (034)

Paper withdrawn

Survey of Glyphosate-Resistant Kochia in Eastern Oregon Sugar Beet Fields. Prashant Jha*[1], Joel Felix[2], Don Morishita[3], Vipan Kumar[4], Anjani J[1]; [1]Montana State University, Huntley, MT, [2]Oregon State University, Ontario, OR, [3]University of Idaho, Kimberly, ID, [4]Montana State University-Bozeman, Huntley, MT (035)

Glyphosate-resistant kochia (*Kochia scoparia* L. Schrad) was confirmed in sugar beet fields in Oregon and Idaho in 2014. A random field survey was conducted in eastern OR sugar beet fields, field edges/fence lines, ditch banks, and beet dump area during the summer of 2015. Live plant samples were collected and immediately placed in a – 80 C freezer until they were analyzed. The objective of this survey was to confirm and determine the level of evolved glyphosate resistance on the basis of relative *EPSPS* gene copy numbers in the selected kochia samples. The levels of glyphosate resistance in kochia positively correlated with the *EPSPS* gene copy numbers. The susceptible plants had a single *EPSPS* gene copy. The 10 kochia plant samples from the Payette beet dump area had relative *EPSPS* gene copies ranging from 1.5 to 2.6, which indicates "developing (very low levels) resistance" in the population. Out of the 10 samples collected from Ontario sugar beet fields, the *EPSPS* gene copy numbers ranged from 2.0 to 4.1, indicating "low levels of resistance" to glyphosate. The 10 additional populations collected from Ontario along Highway 201 had *EPSPS* gene copy numbers of 2.4 to 6.6, indicating "low to moderate levels of resistance". None of the populations collected in the 2015 survey had >7 copies of the *EPSPS* gene (highly resistant). The GR kochia populations from sugar beet fields in eastern OR in 2014 had ~ 3 to 8 copies of the *EPSPS* gene. The 2015 survey results indicate that the development of GR kochia in eastern OR sugar beet fields can still be managed. It is advisable to use full use rates of glyphosate per application, with multiple applications (total in-crop of 3,954 g ha^{-1} glyphosate) to prevent further development of kochia populations with low levels of resistance to glyphosate. A "zero seed tolerance" approach for glyphosate survivors needs to be implemented in sugar beet fields. Growers need to proactively manage the GR kochia seed bank with alternative, effective modes of action herbicides in crops grown in rotation with GR sugar beet, with the integration of tillage.

Monitoring Herbicide Resistance in Cereal Weeds: A Syngenta Perspective. Matt A. Cutulle*[1], Donald J. Porter[2], Cheryl L. Dunne[1], Rakesh Jain[3], Gigi Arino[2]; [1]Syngenta Crop Protection, Vero Beach, FL, [2]Syngenta Crop Protection, Greensboro, NC, [3]Syngenta Crop Protection, Vero Beach, FL (036)

Wild oat and Italian ryegrass are problematic weeds in cereal production. Group 1 herbicides that are commonly used to control these weeds include Acetyl CoA carboxylase inhibitors such as Aryloxyphenoxypropianates (FOPs) and Phenylpyrazolin (DENs). Resistance to these chemistries has been known to occur in grass cereal weeds. Syngenta is dedicated to monitoring resistance to ACCase inhibitors and other modes of action in these weeds. Wild oat and Italian ryegrass samples seed samples were collected from fields where weeds were not adequately controlled by Syngenta cereal herbicide products. The samples were screened for sensitivity to multiple group 1 and group 2 (Acetolactate synthase or ALS-inhibitor) herbicides in the greenhouse. Results of samples analyzed in 2005 indicated that greater than 50% of the wild oat populations were resistant to FOP herbicides; comparatively, only 12% were resistant to the DEN herbicide pinoxaden. By 2014 approximately 75% of the collected populations were resistant to FOP herbicides, but only approximately 30% were resistant to pinoxaden. Despite resistance to group 1 herbicides, group 2 herbicides controlled a majority of the wild oat non-peformance samples. Syngenta will continue to provide herbicide sensitivity diagnostics and recomendations to growers dealing with herbicide resistant weeds.

An Overview of Herbicide-Resistant Weeds in Washington. Rachel J. Zuger*[1], Louise Lorent[1], Jeanette A. Rodriguez[2], Caleb C. Squires[1], Nevin C. Lawrence[3], Amber Hauvermale[1], John F. Spring[1], Rick A. Boydston[4], Drew Lyon[1], Ian C. Burke[1]; [1]Washington State University, Pullman, WA, [2]Heritage University, Prosser, WA, [3]University of Nebraska - Lincoln, Scottsbluff, NE, [4]USDA-ARS, Prosser, WA (037)

Herbicide resistance is an issue of increasing importance throughout intensive agricultural areas, especially in systems with few crop rotational options. Much of the eastern Washington is in a dryland, non-irrigated cropping system of either winter wheat-fallow, winter wheat-spring wheat-fallow, or a three year winter wheat-spring wheat-pulse rotation. Limited cropping options lead to limited herbicide rotation opportunities, increasing the selection pressure for herbicide-resistant weed species. In an initial effort to understand the prevalence of resistance in eastern Washington, growers were encouraged to submit weed biotypes with suspected herbicide resistance to the weed science program at Washington State University. Herbicides were applied to weed biotypes based on suspected resistance, and were also screened for cross resistance, at maximum use rates. A dose-response screening was performed for those herbicides that resulted in a lack of control of specific weed biotypes, compared to susceptible biotypes, to determine the GD_{50} of biotypes for each herbicide. Results suggest resistance of 6 Italian ryegrass (*Lolium multiflorum* L.) biotypes to acetyl-Coenzyme A carboxylase (ACCase) inhibitors, 3 Italian ryegrass biotypes to acetolactate synthase (ALS) inhibitors, and 3 of 25 biotypes with suspected cross resistance to both ACCase and ALS inhibitors. Of the 12 wild oat (*Avena fatua* L.) biotypes submitted, 2 were determined to express resistance to ACCase inhibitors. Also, single biotypes of mayweed chamomile (*Anthemis cotula* L.), shepherd's-purse (*Capsella bursa-pastoris* L.), and white campion (*Silene latifolia* Poir) have been identified as ALS-resistant. Results indicate herbicide resistance to ACCase and ALS inhibiting herbicides is widespread in Washington State.

Predicting and Monitoring Weeds Distributions in Dryland Wheat Using Landsat Data. Aron A. Boettcher*[1], Judit Barroso[2], Dan Long[3]; [1]Oregon State University, Corvallis, OR, [2]Oregon State University, Pendleton, OR, [3]USDA-ARS, Pendleton, OR (038)

Weeds are a serious management issue in the U.S., with an estimated $20 B being spent annually in attempted control, causing an estimated $136 B in crop damage each year. Remote monitoring of weeds can provide information about long term changes in weed distribution, management practices, and estimating regional crop yields. Despite this, there has thus far been a lack in our ability to detect, map, and monitor weeds at spatial scales relevant for decision-making. In part, this inability is due to the prohibitively high cost of reference data over broad geographic ranges and environmental conditions. This study examines the potential of hyperspectral on-combine sensing as a source of reference data for mapping weeds distributions in dryland wheat. We compare on-combine visual assessments of weediness along with hyperspectral measurements made during the harvest of a 17 acre field of dryland spring wheat in the Columbia basin. The objective of this study was to use these two sources of reference data as the basis for developing a model predicting weeds distributions in Landsat 8 imagery. In comparing these two methods of generating reference data to map green weed distributions, the highest correlation was found between NDVI at the time of harvest and medium and high density visual weed observations. A good correlation was found when comparing NDVI at the time of harvest to medium and high density weed observations (R^2 of .694, $p < 0.001$). Hyperspectral measurements made in the grain stream did not perform as well as visual estimates for predicting weeds distributions in satellite images, but work to improve the sensitivity of hyperspectral measurements is ongoing.

Sensitivity of 'Bobtail' Wheat to Flufenacet-Metribuzin. Kyle C. Roerig, Barbara J. Hinds-Cook*, Andrew G. Hulting, Carol Mallory-Smith; Oregon State University, Corvallis, OR (039)

Oregon State University screens new winter wheat cultivars for tolerance to herbicides that will likely be applied once the cultivar is released. These trials ensure that sensitivities will be discovered before the cultivar's release. In 2013, 'Bobtail' showed injury and a yield reduction of 28 bushels a^{-1} when treated with flufenacet-metribuzin. Therefore, further studies were conducted to evaluate the effect of planting date and application timing of flufenacet-metribuzin and pyroxasulfone, both group 15 very long chain fatty acid inhibitors, on 'Bobtail' winter wheat. The planting timing of the studies was typical (middle of October) and late (middle of November). The late timing was utilized to capture the cool, wet planting condition due to the onset of early fall rains or delays in planting. Treatments included: untreated, flufenacet-metribuzin at 0.425 lb ai a^{-1} preemergence and delayed preemergence (shoots from at least 1/2"-inch long to wheat spike); pyroxasulfone preemergence at 0.093 lb a^{-1}, delayed preemergence at 0.0664 lb a^{-1}, and delayed preemergence at 0.0664 lb a^{-1} followed by 0.0664 lb a^{-1} postemergence; pyroxasulfone-carfentrazone delayed preemergence and postemergence at 0.14 lb a^{-1}, delayed preemergence at 0.07 lb a^{-1} followed by 0.07 lb a^{-1} postemergence, and postemergence at 0.07 lb a^{-1}. Treatments were applied using a single bicycle wheeled sprayer calibrated to deliver 20 gal a^{-1}. The wheat response was determined by visual evaluations and yield. At both planting timings, flufenacet-metribuzin caused stunting and stand reductions to 'Bobtail' at the preemergent and delayed preemergent timings 18 to 20 weeks after treatment (p=0.05). The preemergent application of flufenacet-metribuzin caused more injury to 'Bobtail' than all other treatments (p=0.05). Flufenacet-metribuzin reduced yield of 'Bobtail' planted at the typical timing at both the preemergent and delayed preemergent application timings. Late planted 'Bobtail' yield was reduced with the preemergent application of flufenacet- metribuzin compared to all other treatments (p=0.05). The delayed preemergent application of flufenacet-metribuzin caused a reduction in 'Bobtail' yield, when planted late, compared to the postemergent application of pyrozasulfone-carfentrazone at 0.07 lb a^{-1} (p=0.05). The results of these studies have led to the recommendation for a reduced rate of flufenacet-metribuzin on 'Bobtail' to overcome stand reduction.

New Liquid Sulfonylurea Herbicides for Cereals. Kenneth L. Carlson*[1], Keith A. Diedrick[2], William L. Hatler[3], Keith D. Johnson[4], Amanda L. Koppel[5], Jeffrey T. Krumm[6], Bruce V. Steward[7], Robert N. Rupp[8]; [1]DuPont Crop Protection, Des Moines, IA, [2]DuPont Crop Protection, Madison, WI, [3]DuPont Crop Protection, Meridian, ID, [4]DuPont Crop Protection, Grand Forks, ND, [5]DuPont Crop Protection, Richland, WA, [6]DuPont Crop Protection, Hastings, NE, [7]DuPont Crop Protection, Overland Park, KS, [8]DuPont Crop Protection, Edmond, OK (040)

Abstract not available

BOLT™ Technology Soybean for Improved Plant-Back Flexibility after Chlorsulfuron plus Metsulfuron-methyl Application in Wheat. David H. Johnson*[1], Kelly A. Backscheider[2], Jessica R. Bugg[3], Hageman H. Larry[4], Jeffrey T. Krumm[5], Scott E. Swanson[5], Bruce V. Steward[6], Michael T. Edwards[7], Robert N. Rupp[8], Robert W. Williams[9], Richard M. Edmund[10], Victoria A. Kleczewski[11], Eric P. Castner[12];[1]DuPont Crop Protection, Des Moines, IA, [2]DuPont Crop Protection, Shelbyville, IN, [3]DuPont Crop Protection, Columbus, OH, [4]DuPont Crop Protection, Rochelle, IL, [5]DuPont Crop Protection, Hastings, NE,[6]DuPont Crop Protection, Overland Park, KS, [7]DuPont Crop Protection, Pierre Part, LA, [8]DuPont Crop Protection, Edmond, OK, [9]DuPont Crop Protection, Raleigh, NC, [10]DuPont Crop Protection, Little Rock, AR, [11]DuPont Crop Protection, Middletown, DE, [12]DuPont Crop Protection, Weatherford, TX (041)

Abstract not available

Rotational Crops Response to Mesosulfuron/Thiencarbazone Applied in Prior Wheat Crop. Traci Rauch*[1], Joan Campbell[1], Monte D. Anderson[2]; [1]University of Idaho, Moscow, ID, [2]Bayer CropScience, Spangle, WA (042)

Mesosulfuron/thiencarbazone is a premix that will soon be registered in winter wheat to control grass weeds, including rattail fescue. Currently, few postemergence herbicide options exist or provide effective rattail fescue control. Mesosulfuron/thiencarbazone will control rattail fescue as a postemergence herbicide. Mesosulfuron/thiencarbazone is a group 2 herbicide that inhibits acetolactate synthase (ALS) production. Some ALS herbicides used in wheat can impact rotational crops planted in the following year. Studies were initiated in spring 2014 at Genesee, ID and Spangle, WA to evaluate rotational crop response in 2015. In 2014, mesosulfuron/thiencarbazone was applied at 1X (labeled rate) and 2X rate to wheat, and a 2X rate of mesosulfuron and pyroxsulam were included as standards. The experiment design was a randomized split-block with 4 replications. Main plots were the rotational crops and subplots were the herbicide treatments and the untreated check. Rotational crop response was evaluated visually where 0% represented no injury and 100% represented complete crop death. Rotational crops were harvested for seed at maturity. At Genesee, pyroxsulam and the low rate of mesosulfuron/thiencarbazone injured lentil 14 and 10% at 45 days after planting, which was the maximum visual injury observed. Lentil seed yield tended to be lower in the pyroxsulam treatment. Pea, chickpea, lentil and canola visual injury was greater in the pyroxsulam treatment than all other herbicides at Spangle at all evaluation times. Chickpea and lentil seed yield tended to be lower for pyroxsulam treatments. The degree of

rotational crop response to pyroxsulam persistence varied by site due to differences in rainfall and soil pH. Mesosulfuron/thiencarbazone did not reduce rotational crop seed yield at either location.

An Analysis of Predictor Variables and Sampling Dates in the Estimation of Crop Yield Injury. Aron A. Boettcher*[1], Judit Barroso[2], Dan Long[3]; [1]Oregon State University, Corvallis, OR, [2]Oregon State University, Pendleton, OR, [3]USDA-ARS, Pendleton, OR (043)

Traditionally, most prediction yield loss models explain yield loss as a function of weed plant density. Other models use relative leaf area of weeds, weed biomass, or percentage of weed cover to predict yield loss. However, which of these variables predict yield loss more accurately is unknown and will depend on several factors like, predominant weed community, water availability, temperature, type of crop, and time of sampling among others. This study is being conducted to test and compare the efficiencies of weed plant density and percentage of weed cover in predicting spring oilseed (*Brassica carinata*) and spring wheat (*Triticum aestivum*) yield losses at different sampling times (early-season, mid-season, and at harvest) in the inland PNW. Weed density and weed percentage of cover were significant predictors of yield loss ($r^2 \leq 0.88$, $P<0.05$). Weed sampling at mid-season produced the most accurate yield loss predictions. These results indicated that the critical time to control weeds in *B. carinata* might be later than that for spring wheat.

Dry Bean Grower Survey in Minnesota and North Dakota. Rich Zollinger*; North Dakota State University, Fargo, ND (044)

The dry bean grower's survey of varieties grown, pest problems, pesticide use and grower practices has been conducted for 25 years in cooperation with the Northarvest Bean Grower Association, an association of dry edible bean growers in Minnesota and North Dakota. Research and extension faculty at North Dakota State University and the directors of the Northharvest Bean Growers Association developed the survey and were mailed to growers. Participants in the survey were anonymous. Information in the poster summarizes part of the survey's results on weed problems, herbicide use, mechanical weed control practices, desiccant use, and ranking of weeds as the worst production problem. The major weeds in dry edible beans grown in MN and ND were lambsquarters, kochia, pigweed, ragweed, wormwood, and nightshade. Weeds at lower infestations were cocklebur, wild buckwheat, and waterhemp. Bentazon and post-grass herbicides were the dominant herbicides used for weed control followed by imidazolinone herbicides and fomesafen. Dinitroaniline herbicide use has fluctuated but are used for residual control. Cultivation is used on over 35,000 reported acres. Major desiccants used were glyphosate and flumioxazin. Sulfentrazone use as a desiccant is increasing. Weeds rank as major dry bean production problem compared to weather, disease, insects, drought, hail, excess water, delayed planting, emergence/stand, herbicide drift, or harvest problems.

Chickpea Tolerance to Herbicides applied at Ground Cracking. Rick A. Boydston*[1], Ian C. Burke[2]; [1]USDA-ARS, Prosser, WA, [2]Washington State University, Pullman, WA (045)

Postemergence herbicide options are lacking for broadleaf weed control in chickpeas or garbanzo beans (*Cicer arietinum*). In the Southern United States, early postemergence ("at-cracking") applications of paraquat have been used successfully in peanut production to control early emerging weeds with minimal injury to peanut. Chickpea tolerance to applications of paraquat or other herbicides soon after emergence have not been reported. The tolerance of chickpea to paraquat and seven protoporphyrinogen oxidase (PPO) inhibitor herbicides when applied at ground cracking stage was tested in green house trials and field trials. Chickpeas, var. 'Sierra' were planted in potting soil in the greenhouse and PPO inhibitor herbicides or paraquat were applied when chickpeas shoots had emerged 1 to 2 mm. All treatments included nonionic surfactant at 0.25% (v/v) spray solution. Chickpea injury at 1 and 2 weeks after treatment (WAT) was greatest with fomesafen, acifluorfen, saflufenacil, and sulfentrazone, ranging from 34 to 73% and 19 to 32%, respectively. Chickpea injury at 1 WAT was least with fluthiacet at 7 g ai ha^{-1}, carfentrazone at 18 g ai ha^{-1}, pyraflufen at 4 g ai ha^{-1}, and paraquat at 140 g ai ha^{-1} and 280 g ai ha^{-1} ranging from only 7 to 16% and injury decreased over time up to 3 WAT. Paraquat at 140 g ai ha^{-1} and 280 g ai ha^{-1}, fluthiacet at 7 g ai ha^{-1}, saflufenacil at 25 g ai ha^{-1} and sulfentrazone at 140 g ai ha^{-1} did not reduce chickpea dry weight at 3 WAT. In field trials, chickpea var. 'Billy bean' tolerance to paraquat at 140 g ai ha^{-1} and saflufenacil at 50 g ai ha^{-1} applied 1, 4, 7 and 10 days after chickpea emergence (DAE) was tested near Pullman, WA. No spray adjuvants were included. Plots were kept free of weeds season long by using labeled preemergence herbicides and hand weeding. On June 2, 2015 chickpea injury was least (7% or less) following paraquat or saflufenacil applied at 1 or 4 DAE. By July 5, 2015 chickpea injury was 5% or less with all treatments and application timings. Yield of chickpeas was not affected by early season application of paraquat or saflufencil at 1 to 10 DAE. Chickpeas, having an indeterminate growth habit, appear to tolerate paraquat and several PPO inhibitor herbicides when applied immediately or very soon after chickpea emergence.

Degradation of Soil-Applied Herbicides under Limited Irrigation. Daniel Adamson*[1], Andrew R. Kniss[1], Gustavo M. Sbatella[2]; [1]University of Wyoming, Laramie, WY, [2]University of Wyoming, Powell, WY (046)

Soil-applied herbicides are important for controlling weeds in many crops, as they offer a broadened control spectrum and chemical diversity, especially when fewer POST-applied herbicides are available. However, if soil-applied herbicides persist in the soil too long, there is risk for damage to susceptible rotational crops in succeeding years. As herbicide degradation in the soil is highly dependent on water, imminent needs to reduce agricultural water use in the future could lead to limited herbicide degradation and a greater risk for carryover. This project seeks to understand how limited irrigation affects the efficacy and carryover of soil-applied herbicides in Wyoming's irrigated crop rotations. A two year field study is currently being undertaken by applying four different soil-applied herbicides to dry beans and corn respectively. In 2015, corn and dry beans were grown under three irrigation regimes (100, 80, and 69 % of crop evapostranspiration), and soil moisture was monitored using GS1 soil moisture sensors. Volumetric soil water content of the three irrigation treatments averaged 22%, 18% and 17% throughout the growing season. Crop yields decreased as irrigation was reduced. Soil samples collected at regular intervals following herbicide application will be analyzed in 2016 for herbicide level and used to perform a greenhouse bioassay to determine crop response to residual herbicide. Crop response will also be evaluated in the field during the second year when sugar beet, sunflower, and dry bean or corn will be planted over the original plots and assessed for herbicide damage.

Reduced Rates of Metribuzin and Hilling for Weed Management in Potato. Mustapha A. Haidar*, Walaa A. Siblani; American University of Beirut, Beirut, Lebanon (047)

The current emphasis on reducing herbicide application has led to an increase in alternative weed control measures. Thus, a field experiment was conducted in spring of 2014-2015 to examine the effect of various combinations of hilling-time and reduced rates of metribuzin application on weed infestation in potato and to determine their impact on potato yield. Metribuzin at 0.18, 0.35, 0.65, or 0.75 kg ai/ha with or without hilling 6, 7 and 8 weeks after planting (WAP) were used. Results showed that metribuzin at all tested rates, with or without hilling, significantly reduced weed infestation after 50, 70 and 110 days after planting compared to the check. While, hilling alone was not significantly different from the check. Best results considering both long season weed management, selectivity and marketable yield of potato was obtain by a combination of metribuzin at all tested rates with hilling 6, 7 and 8 WAP. None of the metribuzin treatments was toxic to potato plants compared to the hand weeded plots. The results suggest that metribuzin at 0.35 supplemented with hilling may suppress long season weeds with 53% less metibuzin (ai/ha) and provide tuber yield comparable to conventional standard application of metribuzin (0.75 kg ai/ha).

Scouring Rush (*Equisetum hyemale*) Control in Sugarbeets. Gustavo M. Sbatella*; University of Wyoming, Powell, WY (048)

Scouring rush is found growing in sugarbeet fields in Northwest Wyoming, competing for resources and interfering with crop harvest. Scouring rush control is challenging because the plant has thick waxy cuticle, high silica content, and rhizomatous growth. Information available on scouring rush control is mainly focus in rangelands and pastures, and there is limited information regarding control in sugarbeet. A field study was conducted near Powell, WY, with the objective to determine the efficacy of herbicides currently labeled for use in sugarbeet for scouring rush control. Clopyralid, phenmedipham + desmedipham, triflusufuron, were tank mixed with glyphosate and applied at different rates, and timings. Control efficacy was estimated by counting the number and height of stems present in permanent quadrants, before and after herbicide applications. Stems were harvested for biomass estimation. Crop injury from treatments was visually estimated. Scouring rush stem density before applications was 10 stems per ft^2 with an average height of 17 inches. Although height and number of stems were impacted with herbicide applications, values were higher than recorded previous to applications. All treatments reduced scouring rush biomass with the exception of glyphosate tank mixed with triflusufuron. Crop injury was recorded in all treatments that included clopyralid and phenmedipham + desmedipham. Scouring rush control was not satisfactory with any of the tested treatments. There is a need to further explore options for successful control of scouring rush in sugarbeet.

Greenhouse Evaluation of Chemical Control for Mid-Season Weeds in Chile Peppers. Taylor Mesman*, Brian J. Schutte, Edward Morris; [1]New Mexico State University, Las Cruces, NM (049)

Weed management in chile pepper is challenged by a prolonged period in which weeds must be controlled to preserve maximum yield potential. Soil-applied herbicides are often sprayed around the time of crop thinning, which is typically 9 to 10 weeks after seeding. The herbicide adjuvant Grounded® (Helena Company) is promoted to enhance adsorption and performance of soil-applied herbicides; however, to our knowledge, Grounded is not widely used in chile pepper in New Mexico. The objective of this study was to determine the effects of Grounded on the control outcomes for three soil-applied herbicides that are registered for post-direct applications to chile pepper (halosulfuron-methyl, s-metalochlor, pendimethalin), as well as one candidate herbicide for chile pepper (flumioxazin). To accomplish this objective, a greenhouse study was conducted during the fall of 2015. Treatments included an unsprayed control and herbicides with and without Grounded at 1% v/v. Herbicide application rates were 0.05 kg ai ha^{-1} for halosulfuron-methyl, 1.42 kg ai ha^{-1} for s-metalochlor, 1.58 kg ai ha^{-1} for pendimethalin and 0.107 kg ai ha^{-1} for flumioxazin. Herbicides were applied using a moving-nozzle spray chamber. Experimental units were flats filled with a sand-soil mixture. The experimental design was a split-plot, with herbicide as the main plot factor and Grounded as the subplot factor. Main plots were arranged in randomized complete blocks with four replications. At 0, 7, 14, 21 and 28 days after spraying (DAS), palmer amaranth seeds (50 seeds DAS^{-1}) were sown to the 1-cm depth. Seedling emergence data were used to calculate percent control relative to the unsprayed control. Within herbicide treatments and for each DAS, the effects of Grounded on percent control were evaluated with binomial generalized linear mixed models. Throughout the experiment, flats were watered as needed to prevent both crusting on the substrate surface and leaching from flat bottoms. Results indicated that Grounded increased the durations of control for pendimethalin and flumioxazin. Grounded did not influence control outcomes for halosulfuron-methyl, which generally provided poor control of Palmer amaranth (30% control at 28 DAS). Grounded did not influence control outcomes for s-metalochlor, which generally provided excellent control of Palmer amaranth (100% control at 28 DAS). These results suggest that Grounded can improve control outcomes for some soil-applied herbicides sprayed at chile pepper thinning. These results will guide herbicide evaluations conducted under field conditions.

Tolerance of Peppermint and White Clover to Dormant Application of Saflufenacil. Kyle C. Roerig, Carol Mallory-Smith, Andrew G. Hulting, Pete A. Berry*; Oregon State University, Corvallis, OR (050)

Saflufenacil is a protoporphyrinogen oxidase (PPO) inhibitor with the potential to be used as a broadleaf burndown herbicide in several perennial crops in the Pacific Northwest. Growth of weeds during the winter season in perennial crops can decrease yield potential due to competition that occurs in the spring once crop dormancy is broken. The current agronomic practice for managing weeds in mint and clover is paraquat applied with a soil active herbicide to reduce weed potential by "burning down" broadleaves and grasses, whether crop or weed, and by inhibiting germination. This study compared the use of saflufenacil as a burndown with current herbicide use practices to determine the potential of replacing the more toxic paraquat (LD50 150 mg/kg) with a less toxic and equally effective herbicide. Plots of spearmint, white clover, and red clover were treated during the winter to determine the percent burndown and the subsequent regrowth until harvest. Saflufenacil had a greater percent burndown or was equivalent to the highest percent burndown compared to other herbicides used in the study. There was no difference (p-value $<$ 0.05) in regrowth, yield, or percent oil for white clover, red clover, or spearmint, respectively, between saflufenacil and the labeled herbicides. The results demonstrate saflufenacil, which has a higher LD50 (>2000) and lower use rate, has the potential to be an effective alternative to herbicides currently used for burndown in specialty crops in the Pacific Northwest if registered for use in clovers and mints.

Integrated Weed Management for Conventional Canola (*Brassica rapa*) in Eastern New Mexico. Christopher A. Landau*[1], Brian J. Schutte[1], Sangu Angadi[2], Abdel Mesbah[2]; [1]NMSU, Las Cruces, NM, [2]NMSU, Clovis, NM (051)

Growers in eastern New Mexico are increasingly interested in winter canola because of its ability to be used in rotation with the winter wheat. However, integrated control programs have yet to be developed for conventional canola grown in eastern New Mexico. The overall objectives of this project were to: (1) evaluate registered herbicides for control shortcomings in conventional canola, and (2) to determine the potential for weed suppression through increased canola seeding rate. These objectives were addressed by conducting two field experiments in Clovis, NM. The first field experiment determined the abilities of sethoxydim (0.210 kg/hectare for the low rate and 0.525 kg/hectare for the high rate) and clopyralid (0.105 kg/hectare for the low rate and 0.210 kg/hectare for the high rate), both separate and in a tank mix, to control common weeds in canola during spring. Fall weed control was provided by trifluralin applied at 0.140 kg/hectare. Results from the first year suggest that currently registered herbicides are able to control grass weeds in canola; however, flixweed (*Descurainia sophia*) and western tansymustard (*Descurainia pinnata*), which are broadleaf weeds belonging to the same family as canola (Brassicaceae), are difficult to control with herbicides alone. The second field experiment was conducted to determine how increasing canola seeding rates (0.5, 1.0, 1.5, 2.0, and 2.5 x the recommended seeding rate of 250,000 seeds $acre^{-1}$) influenced light transmittance through the canola canopy. Light transmittance data was collected to demonstrate the canola's ability to suppress weeds. The data suggests that as seeding rate increases, light transmittance decreases for both the fall and spring. Developing management systems for troublesome weeds in the region is critical for making conventional canola a viable option for growers in NM, and may be able delay the development of herbicide resistant weeds.

Palynology of Weedy Species. Shaheen Bibi*, Karl Ravet, Kimberly Vanderpool, Todd Gaines, Philip Westra; Colorado State University, Fort Collins, CO (052)

The study of pollen (palynology) is a major tool used for plant taxonomy because pollen micro-morphological features such as diameter, shape and coat ornamentations are specific to a genus. Species in Chenopodiaceae such as *Kochia scoparia* generally have spherical and pantoporate pollens. Pores allow for pollen tube emergence. The external pollen coat is constituted by an inner layer (intine) and an outer layer (exine). Exine allows for long-term viability. Its surface is ornamented with microspines. A major component of the exine is the phenylalanine-derived biopolymer sporopollenin. Glyphosate resistant (GR) crops have been engineered through the utilization of glyphosate-insensitive EPSPS (e.g., CP4 EPSPS) under the control of heterologous promoter (e.g., CaMV35S promoter). Although this strategy confers glyphosate resistance, the lack of sufficient EPSPS expression driven by the CaMV35S promoter in pollen required the addition of CP4 EPSPS with the rice actin promoter to enable crop safety for glyphosate applications later in crop development. Several studies in rice and corn showed that pollen viability of the GR crops may be reduced following developmentally-late glyphosate treatment. Glyphosate inhibits EPSPS, which alters the synthesis of aromatic amino acids such as phenylalanine. Therefore, potential EPSPS inhibition in reproductive organs of GR crops may affect sporopollenin synthesis, with potential consequences for pollen viability and ultimately seed yield. In this work, we are revisiting the use of palynology to understand the effect of glyphosate on the development of reproductive organs. We are comparing the efficiency of the transgenic approach (35S::CP4EPSPS) and the evolved approach (increased EPSPS copy number under endogenous promoter) in maintaining pollen viability following glyphosate application. We will use electronic microscopy techniques to assess the impact of glyphosate on the development of reproductive organs in GR and glyphosate susceptible *Kochia scoparia* and *Palmer amaranth* populations and GR crops. We are developing an approach to specifically look at the sporopollenin content using fluorescence confocal microscopy.

Hairy Nightshade Seed Production Through the Growing Season. Samara L. Arthur*, Don Morishita, Kyle Frandsen, Michael L. Thornton; University of Idaho, Kimberly, ID (053)

Hairy nightshade (*Solanum physaliolium* Rusby) is a summer annual weed that infests many irrigated crops in southern Idaho. In dry bean production, it is particularly competitive and can also reduce the quality of the crop. If harvested, fruit will stain the beans. It will continue to emerge through the summer, herbicides applied in the spring have often dissipated before the crop can shade hairy nightshade plants and reduce their growth. A preliminary study was initiated in 2015 at Kimberly, ID to determine fruit and seed production of plants sown weekly over a growing season. Initial planting was started May 18 and continued for 14 weeks with 4 plants per week. The average number of fruit and seed produced per plant from week 1 planting was 11,442 and 276,902, respectively. Fruit and seed production declined logarithmically from the first planting date. However, seed production per fruit did not significantly drop until week 11. Weeks 1 through 10 ranged from 19 seeds to 24 seeds per fruit and averaged 23 seeds per fruit. Average seed per fruit from week 11 through 14 averaged 9 seed per fruit. This preliminary study of methods and materials will assist in a completely random design study to be conducted the next growing season to gain information for making proper decisions in crops where hairy nightshade is a problem.

Growth Response of Roughstalk Bluegrass and Tall Fescue to Waterlogging. Mingyang Liu*, Andrew Hulting, Carol Mallory-Smith; Oregon State University, Corvallis, OR (054)

Roughstalk bluegrass (*Poa trivialis*) is a weed species reported more frequently during the past decade by Oregon cool season grass seed growers. This species is often found in the fields with waterlogged soils, indicating tolerance to waterlogging may promote this species. The objective of this study was to identify the morphological or physiological traits of roughstalk bluegrass which might contribute to waterlogging tolerance. Roughstalk bluegrass and tall fescue (*Festuca arundinacea*), a cool season grass seed, were subjected to a waterlogging treatment in the greenhouse. At the end of the study (28 d), the dry aboveground biomass, turf quality, leaf number, plant height, leaf water soluble carbohydrate content, and chlorophyll content of both species were reduced by the waterlogging treatment compared to the control. But no differences were found between the species for these measures. However, the root length increased by 5% in waterlogging treated tall fescue, but was reduced by 41% in waterlogging treated roughstalk bluegrass. The root dry weight and root water soluble carbohydrate content were reduced by 43 and 31% by waterlogging in tall fescue and 12 and 10% in roughstalk bluegrass, respectively. The shorter but thicker roots may help roughstalk bluegrass obtain oxygen from the top layer of the soil thus avoiding waterlogging stress. The greater root water soluble carbohydrate reserves in roughstalk bluegrass may provide substrate to maintain energy generation during waterlogging.

Project 4. Teaching and Technology Transfer

Model-based Software for Teaching Tall Morningglory Seedbank Density Effects on Chile Pepper Production. Brian J. Schutte*; NMSU, Las Cruces, NM (055)

Tactics that target the seedbank are important components of integrated weed management strategies for chile pepper production. However, such tactics are difficult for growers to adopt because specific, tangible consequences of seedbank reduction are unclear. To better understand the economic benefits of management interventions aimed at seedbanks, this project developed a model that provides insight on the outcomes of seedbank reduction. The model focused on tall morningglory (*Ipomoea purpurea*) and emphasized pendimethalin, which is a pre-emergence herbicide that is often applied at the time of crop thinning; during the period of tall morningglory emergence. The model was built using data from field studies conducted in 2014 and 2015. Field studies determined: 1) tall morninglory seedbank density effects on pendimethalin control outcomes, 2) tall morningglory seedling density effects on hoe time requirements, and 3) tall morningglory plant density effects on harvest efficiency. Results indicated that approximately 4% of nondormant seeds produced seedlings that escaped pendimethalin applied at 0.16 kg ai ha^{-1}, 26% of nondormant seeds produced seedlings that escaped pendimethalin applied at 0.08 kg ai ha^{-1}. Each additional tall morningglory seedling that escaped pendimethalin increased the time required to hoe 10-m of crop row by 3.6 seconds. If seedlings were not hoed, each additional tall morningglory plant decreased the amount of chile pepper harvested in 1 min by 10 g. These data were used to develop a model-based software program that allows users to discover the practical implications of additions to tall morningglory seedbanks. Following parameter specification by the user, the model produces per-acre-estimates for: (1) tall morningglory seedling densities after pendimethalin, (2) hoe time requirements after pendimethalin and, (3) if tall morningglory escapes are not controlled, additional time harvesting to acquire yield goals. Response variables are presented as functions of tall morningglory seedbank density, which allows users to recognize the role of tall morningglory seedbank density on weed control outcomes, weed control costs and crop production expenses. It is expected that the model-based software program will be an important tool for improving knowledge on weed seedbank management.

A look back on the 2015 National Weed Contest hosted by The Ohio State University. Bruce A. Ackley*; The Ohio State University, Columbus, OH (056)

Abstract not available

Digital Books for Weed Identification. Bruce A. Ackley*; The Ohio State University, Columbus, OH (057)

Plant identification can be challenging and even intimidating for the inexperienced. Growers do not necessarily need to identify every weed in a field to be effective managers, but should be able to identify the major weeds that are important to their operations 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 tends to dominate disturbed habitats within any native landscape. This iBook, "The Ohio State University Guide to Weed Identification", was 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. The iBook provides a new way to use an old tool - visualization - in the world of weed identification. Plant descriptions contained herein include key identification characteristics, photos of many species at different stages of maturity, and 360-degree movies for most species in the book. This book is not meant to be a compendium of all weedy plants in the U.S., but rather includes a number of the most common Midwestern U.S. weeds and the basic intellectual tools that are necessary to successfully identify plants.

Crop Management Field School. Gregory J. Endres*; NDSU, Carrington, ND (058)

This annual one-day field event conducted in mid-June at the NDSU Carrington Research Extension Center provides in-season agronomy and pest mangement updates in demand by crop advisers. Instructors include the NDSU Extension Service and research agronomists, and pest management scientists and specialists. Cncurrent sessions include the basic categories of pest, crop, and plant nutrition/soil management. In 2015, sessions included: 1) Weed identification - Idendify about 60 living weed exhibits with a brief review of bilology and control, 2) Herbicide site-of-action - Identify selected herbicide classes by examining crop and weed injury symptoms, 3) Corn POST-nitrogen application, and 4) Intensive soybean management. The participants received information which immediately could be utilized during the balance of the crop season and beyond. School challenges include potential for adverse weather conditions (e.g. rain or high wind). Participants are asked to complete a one-page evaluation form. A summary of selected results from the 2015 school include: 1) With a range of 0 (poor) and 4 (excellent) to rate session usefulness, the four 2015 sessions had values ranging from 3.5 to 3.8, and 2) Weed science sessions were commonly listed as having most vlaue.

Project 5. Basic Biology and Ecology

Evaluation and Development of Physical Drift Reduction Adjuvants, Vapor Drift Reduction Adjuvants and Physical and Vapor Reduction Combination Adjuvants with Several Dicamba and 2,4-D Formulations. Jim T. Daniel*[1], Philip Westra[2]; Kirk A. Howatt[3], Scott Parrish[4], [1]Consultant, Keenesburg, CO, [2]Colorado State University, Fort Collins, CO; [3]North Dakota State University, Fargo, ND, [4]AgraSyst, Spokane, WA (059)

Increase use of phenoxy herbicide tank mixes with glyphosate herbicide as a means to manage developing herbicide resistance has lead to the discovery of increased physical and vapor drift of 2,4-D dimethyl amine salt (DMA), dicamba DMA salt and dicamba diglycolamine salt (DGA), when applied with ammonium sulfate (AMS) and/or nonionic surfactant (NIS). New drift reduction and volatility reduction adjuvants are now under development to help manage these issues. Field and greenhouse evaluations have demonstrated the ability of AQ922, AQ889, AQ1000 and AQ2005 to reduce herbicide movement through drift reduction and volatility reduction when applied as adjuvants in the use rate range of 0.125% v/v to 1% v/v of the spray solution.

Physiological Mechanisms of Shade Avoidance Response in *Beta vulgaris*. Albert T. Adjesiwor*, Thomas J. Schambow, Andrew R. Kniss; University of Wyoming, Laramie, WY (060)

Light reflected from leaves of plants has a reduced red to far-red ratio (R:FR). Most plants use this as a cue to perceive impending competition. In response to reduced R:FR, plants adopt morphological and physiological strategies to avoid the perceived impending competition (shade avoidance). Shade avoidance can therefore result in sink monopolization which can affect photosynthate partitioning. Though the economic yield of *Beta vulgaris* is sucrose, the effects of shade avoidance on carbohydrate (CHO) partitioning and storage is not known. In three separate studies conducted in 2014 and 2015, we evaluated effects of reflected R:FR from grass (Kentucky bluegrass) on non-structural carbohydrates in *B. vulgaris*. There were two treatments: grass and soil (no grass) surrounding *B. vulgaris*. Roots of grasses were isolated from *B. vulgaris* to ensure there was no competition for water and nutrients. *B. vulgaris* was sampled at 90 days after planting (DAP) in 2014, and 56 and 73 DAP in 2015. In two (56 and 73 DAP in 2015) out of three studies, *B. vulgaris* root starch and soluble CHO were similar between grass and control treatments. When harvested at 90 DAP in 2014, the ratio of root starch to soluble CHO was higher in *B. vulgaris* exposed to the grass treatment compared to soil control treatment (P=0.02). These results provide some evidence that shade avoidance may affect the proportion of CHO stored as soluble sugars and starch in roots of *B. vulgaris.*

Crop Canopy Effects on Growth and Fecundity of Kochia at Different Densities. Charlemagne A. Lim*[1], Prashant Jha[1], Vipan Kumar[2], Anjani J[1], Shane Leland[2]; [1]Montana State University, Huntley, MT, [2]Montana State University-Bozeman, Huntley, MT (061)

Paper withdrawn

Measuring Jointed Goatgrass (*Aegilops cylindrica*) Seed Bank Longevity with Stable Carbon Isotopes. David A. Claypool*, Andrew R. Kniss; University of Wyoming, Laramie, WY (062)

The use of stable isotope-labeled CO_2 to 'tag' plants is being explored as a way to quantify seed longevity in the soil seed bank. If successful, this method provide an *in situ* alternative to commonly used, but highly artificial seed burial methods. Preliminary greenhouse results indicated that ^{13}C in excess of natural abundance can be passed on to the seed after only a 2 hour exposure to the maternal plant. A field study was initiated in 2010 in which jointed goatgrass was exposed to 99 atom-%$^{13}CO_2$ at seed fill. Seed samples of the F_1 generation were collected from the treated area at maturity in July. Emerging seedlings were then collected from the same area in March 2011, October 2011, and November 2012. At each sampling date, plants were also collected from an area that did not receive $^{13}CO_2$. These control samples were analyzed for $\delta^{13}C$ (ratio of ^{13}C to ^{12}C) to quantify the natural abundance signature, and a 99% prediction interval for the control samples was calculated. Any seed or seedling from the treatment area that had a $\delta^{13}C$ value greater than the upper 99% prediction interval was assumed to be an F_1 seed produced in 2010. All of the F_1 seed produced in 2010 had a significantly greater $\delta^{13}C$ value compared to the control sample. This result confirms the $^{13}CO_2$ tagging treatment worked as planned, as 100% of the produced F_1 seed was distinguishable from non-tagged plants. When seedlings (with joints still attached) were collected in March of 2011, 94% of the seedlings carried the ^{13}C signature. The remaining 6% of seedlings collected at this sampling date are presumed to have been from seed produced before 2010, or possibly imported into the sampling area by field operations. Our data illustrate that a stable carbon isotope approach can be used to experimentally quantify seed longevity with minimal artificial seed processing or site disturbance. Seedling samples from subsequent sampling dates in 2011 and 2012 are currently being prepared for analysis.

Characterization of Vernalization Requirements and Expression of *BdVRN1* in *Bromus tectorum*. Nevin C. Lawrence*[1], Amber L. Hauvermale[2], Ian C. Burke[2]; [1]University of Nebraska - Lincoln, Scottsbluff, NE, [2]Washington State University, Pullman, WA (063)

Variation in phenology of downy brome is a key factor in the success of the species as an ecological invader of natural areas and competitor within agronomic fields. Prior research documented differing vernalization requirements of downy brome collected from different environments, however no previous work has characterized the connection between phenotypic responses and genotypic control of downy brome vernalization. As most variation in vernalization requirements of wheat and barley have been attributed to variation of *VRN1*¸ quantifying the expression of a *VRN1* orthologue in downy brome may help explain the genetic controls regulating downy brome phenology. A series of common garden and greenhouse experiments were conducted to: (1) characterize the vernalization requirements of downy brome accessions and (2) determine if expression of *VRN1* orthologues can be linked to contrasting rates of development. Eight accessions from a larger collection of 96 were used to quantify vernalization requirements and *VRN1* expression. Each accession was exposed to 0, 2, 4, 6, or 8 w of vernalization at 3°C and observed for flowering response. Leaf tissue was collected from each treatment for RNA extraction and later reverse transcribed into cDNA to quantify expression of a downy brome *VRN1* orthologue. Greater than 70% of replicates from all accession flowered after 6 w of vernalization. No replicates from one of the tested accessions flowered regardless of vernalization treatment. Expression of a *VRN1* orthologue was only observed in treatments were flowering did occur, suggesting that the molecular controls of flowering in downy brome are likely similar to related species.

Seed Germination Dynamics of Herbicide-Resistant and Susceptible Populations of *Kochia scoparia*. Vipan Kumar*, Prashant Jha, Shane Leland, Anjani J, Charlemagne A. Lim; Montana State University, Huntley, MT (064)

Herbicide-resistant (HR) kochia is an increasing management concern for growers in the US Great Plains. To better understand the evolution of herbicide resistance and develop effective management strategies for HR kochia, it is important to understand the seed germination characteristics of HR vs. herbicide-susceptible (SUS) kochia, and investigate a possible link between the seed dormancy and herbicide resistance levels. In this study, seven glyphosate-resistant (GR), four dicamba-resistant (DR), and two SUS kochia populations collected from wheat-fallow fields in northern Montana were investigated. Seeds obtained from the selfed GR and DR kochia plants that survived glyphosate at 1740 g ha^{-1} and dicamba at 280 g ha^{-1}, respectively, and grown under pollen isolation conditions in the greenhouse in 2014 were used. All seeds were stored at room temperature until used. The main objectives of this study conducted in 2015 were (1) to characterize the levels of resistance to glyphosate and dicamba in the selected GR and DR kochia populations, respectively, and determine the *EPSPS* (5-enol-pyruvylshikimate-3-phosphate synthase) gene copy number (mechanism of glyphosate resistance) in GR populations, (2) compare the germination pattern of GR, DR, and SUS populations at constant (5, 10, 15, 20, 25, 30, 35 C) and fluctuating (12 h low/12 h high) temperatures of 5/10, 10/15, 15/20, 20/25, 25/30, 30/35 C, and (3) to determine the relationship between the percent cumulative germination and herbicide resistance levels. Whole-plant dose-response experiments indicated that the GR kochia populations were 8- to 14-folds more resistant relative to the SUS populations based on the percent control ratings (LD_{50} values). The level of resistance had a positive correlation (r = 0.8452; P = 0.0041) with the EPSPS gene copy numbers (3 to 13) of the GR populations. Except three populations, the percent cumulative germination of GR kochia populations was lower than the SUS populations at the evaluated constant or fluctuating temperatures. However, there was no significant correlation between the cumulative germination and glyphosate resistance levels (LD_{50} values or EPSPS gene copies). The four DR kochia populations showed up to 7-fold levels of resistance to dicamba relative to the two SUS populations. The percent cumulative germination of the DR populations was lower than the SUS populations at all constant or fluctuating temperatures, with greater differences at low temperatures of 5, 10, 15, 5/10, and 10/15 C. Also, a strong negative relationship between the cumulative germination and levels of dicamba resistance was observed in the DR populations at all temperatures tested. Results indicate that the level of glyphosate resistance does not correlate with the seed dormancy of GR kochia; however, DR seeds were more dormant and expected to be more persistent in the soil seed bank relative to the SUS kochia populations.

Methods for Confirming Resistance to Different Herbicide Modes of Action: Does One Size Fit All? Carl W. Coburn*, Andrew R. Kniss; University of Wyoming, Laramie, WY (065)

The selectivity index (SI) is a measure of herbicide resistance that is reported for various weed species and herbicide modes of action. There is evidence that experimental methods (such as pot size and soil type) and the response variable (dry weight, injury, mortality) may influence ED_{50} (dose resulting in 50% response) and SI values. Greenhouse experiments were conducted to determine the effect of pot size and response variable on the SI using *Chenopodium album* (common lambsquarters) biotypes treated with atrazine or glyphosate; and *Kochia scoparia* (kochia) biotypes treated with dicamba. Susceptible and resistant biotypes of each species were planted in four different pot sizes (750, 1200, 1500, and 3800 cm^3) except for atrazine treated plants, which were only planted in two pot sizes (1200 and 1500 cm^3). Herbicide doses were chosen relative to the field use rate for each herbicide, with 3 replicates per dose. A log-logistic model was used to quantify the response of each biotype to the herbicide. Above and below ground biomass, visual injury, and mortality were assessed. For glyphosate and dicamba treatments, smaller pot size resulted in higher ED_{50} values compared to larger pots for most response variables, but the effect on SI was inconsistent. Atrazine treated plants had lower ED_{50} values for all response variables when grown in smaller pots. Mortality resulted in the highest ED_{50} values relative to other response variables for all herbicides and species tested.

GENERAL SESSION

Welcome to Albuquerque. Richard J. Berry*; Mayor, Albuquerque, NM (066)

Introduction – Meeting Announcements. Kirk A. Howatt*; North Dakota State University, Fargo, ND (067)

The program includes 62 posters and 89 papers, 6 of which are in the General Session. Student contest presentations total 46 of the 145 submitted presentations, 20 posters and 26 papers.

Total (student) numbers

Undergraduate posters 4 (3)

Range posters 15 (6), papers 17 (5)

Horticulture posters 11 (3), papers 7 (1)

Agronomy posters 22 (6), papers 34 (10)

Teaching/Technology posters 4 (0), papers 7 (1)

Biology/Ecology posters 6 (2), papers 16 (9)

Education/Regulatory papers 2 (0)

General Session papers 6

Three posters (14, 34, and 61) and two papers (102 and 123) have been cancelled. Two posters (3 and 43) are present but will not be in the student contest. One poster (22) and one paper (152) have been added to the student contest. The paper (152) is moved to Tuesday at 4:45 to allow judging before the Breakfast meeting. All are reminded that titles should be submitted with all important words capitalized instead of regular sentence capitalization. The Proceedings are still missing 12 abstracts.

Research Section Chair Jane Mangold has worked with project chairs to assemble several discussion sessions. See page 2 of the program for time and location of discussions.

Range and Natural Areas: Weed Risk Assessment as a Decision-Making Tool for Invasive Species Management.

Horticultural Crops: Impact of Increased Irrigation Water Salinity on Crop Injury from Soil Residual Herbicides.

Agricultural Crops: Use of 21st Century Technology in Weed Management.

Teaching and Technology: Reaching Out: Who and How.

Biology and Ecology: How Can We Harness Genetic and Physiological Tools to Advance Understanding of Weedy Plants?

Education and Regulatory Chair Sandra McDonald has added a discussion on Herbicides and PPE.

The Public Relations committee has prepared a survey. Please contribute a few minutes to complete the survey. The Western Integrated Pest Management Center Invasive Species Signature Program is sponsoring a training on use of the CLIMEX software program. This program can help identify potential new weed invaders according to changes in environmental conditions.

Presidential Address. Joseph P. Yenish*; Dow AgroSciences, Billings, MT (068)

Welcome to the 69th Annual Meeting of the Western Society of Weed Science. It has been my honor to serve as your president over the past year.

As always, the success of our meeting is the result of the coordinated efforts. Special thanks to program chair and President-Elect Kirk Howatt for all his efforts over the months prior to this meeting. At times it seems like an endless process, reviewing titles, making necessary format changes, and arranging papers into the various sessions in a sensible manner. Additionally, there is the challenge of developing an entertaining and informative general session. Kirk was able to do all that along with his committee; Jane Mangold, Research Section Chair, and Sandra McDonald, Education and Regulatory Chair.

Also, special thanks go to Local Arrangements Chair, Brian Schutte, for effectively coordinating with the hotel staff. Finally, special thanks to our Business Manager, Phil Banks for negotiating an equitable contract with the hotel and making sure things ran smoothly before, during, and after the meeting.

While our society is currently on sound financial footing there are things we need to consider addressing in the near future. We have been below 300 attendees each year since 2016 with a recent low at last year's meeting in Portland. Our financial break-even point for the meeting is assumed to be 300 attendees, thus we may need to adjust to a new reality for financial sustainability. Currently, proceeds from sales of Weeds of the West have sustained our financial position, but those proceeds will end over the next few years. The board has considered many options including merging with other similar western regional organizations. The board has identified similar societies, but to date has not approached nor been approached to discuss merging. We encourage the general membership to consider organizations for potential mergers. On a positive note, the number of students attending and presenting papers has essentially doubled over the past 10 years. This bodes well for the long-term future of the society, but certain actions must be taken in the short run to ensure sustainability.

As many of you know, Phil Banks of Marathon Ag has informed us of his intent to resign as WSWS Business Manager at the end of the 2017 Annual Meeting in Coeur d'Alene, ID. We greatly appreciate Phil's efforts and guidance over the past several years and regret ending that relationship. At the same time, we realize we must move forward in finding a suitable replacement. To that end, we have entered into a joint search with the WSSA, NCWSS, and SWSS organizations along with the North American Invasive Species Management Associations (NAISMA) to seek a replacement. Additionally, we continue to seek out candidates in conduction with NAISMA only and independently. We have some advantage in that our Business Manager contract expires later than each of the other organizations mentioned. Currently, we feel good about the applications in front of us. Similarly, we feel there are viable options should we continue recruiting. We have no set timeline, but expect to have an individual or organization identified by our summer board meeting.

Finally, I'd like to end where I began in saying it is truly an honor to have served as your President. This meeting marks my 20th WSWS meeting and 2016 marks the 20th anniversary of my moving to the western U.S. The West is truly my home and I love all aspects of the land and the people. I hope you all feel equally at home as a transplant or native.

Washington Update. Lee V. Van Wychen*; Weed Science Society of America, Alexandria, VA (069)

Director of Science Policy Report

WSWS Annual Meeting. Albuquerque, NM, March 8, 2016

National Weed Survey. We had 460 weed scientists and practitioners complete about 650 total surveys in 2015 for the most common and most troublesome weeds in 26 different cropping systems and natural areas. The 2015 survey results can be downloaded at: http://wssa.net/wssa/weed/surveys/. Our plan is conduct this survey every year, but it will be split into a 3 yr rotation going forward. In 2016, we'll survey weeds in broadleaf crops/fruits/vegetables. In 2017, we'll survey weeds in grass crops/pasture/turf. In 2018, it will be for weeds in aquatic/non-crop/natural areas.

FY 2016 and 2017 appropriations- The 2-year budget deal (i.e. the Bipartisan Budget Act of 2015) signed into law in December increased non-defense discretionary spending by $50 billion over the budget caps agreed to under sequestration that began in 2013. The FY 2016 Omnibus funding bill passed by Congress in December was overall good news for weed research because most of our research and capacity funds are non-defense discretionary spending. USDA-NIFA, -ARS, -APHIS, and -NRCS all got modest increases compared to last year. Funding for the Army Corps of Engineers' Aquatic Plant Control Research Program (APCRP), doubled from $4M to $8M; however, half of that is slated for new watercraft inspection stations in the Pacific Northwest (as authorized in the Water Resources Reform and Development Act of 2014). The biggest USDA winner was the Agricultural and Food Research Initiative (AFRI) competitive grants program which saw an increase from $325M to $350M. USDA funding remained constant to last year's levels for the Hatch Act ($244M), Smith-Lever Act section 3(b) & (c) ($300M), IR-4 ($11.9M), and Crop Protection & Pest Management (CPPM-$17.2M), which includes funding for the Regional IPM Centers and Extension IPM. For FY 2017, the president's February budget proposal again proposed modest increases for USDA-NIFA, -ARS, -APHIS, and –NRCS agencies. USDA research "capacity funding" was held constant, while AFRI competitive grants requested $700M, its fully authorized amount and DOUBLE what was appropriated in FY 2016. However, $325M of that increase was requested as mandatory funding and Congress will likely put the kabash on that.

<u>Areawide IPM bill (H.R. 3893)</u>. In November, Rep. Tulsi Gabbard (HI) introduced the Areawide Integrated Pest Management (AIPM) Act of 2015 (H.R. 3893). The bill amends the Integrated Research, Education, and Extension competitive grants program by adding a focus on grants specifically for AIPM. Currently under this section of law, competitive grants are awarded, with such sums as necessary, for Integrated projects as determined by the Secretary in consultation with the National Agricultural Research, Extension, Education, and Economics (NAREEE) Advisory Board. Integrated projects currently funded under this section include Crop Protection and Pest Management (CPPM), the Organic Transitions Program, and the Methyl Bromide Transition program. This bill could be a great source of funding for weed AIPM projects. USDA already has the authority under existing law to "appropriate such funds as necessary". The key is build support both at USDA and in Congress for the AIPM concept so that USDA asks for money for these types of projects and then Congress supports it. WSSA is working with Rep. Gabbard and other groups to build support among stakeholders and find co-sponsors in the Senate. Ideally, we'd like to see this language included in the next Farm Bill. A link to Rep. Gabbard's press release and speech in the House introducing the AIPM bill.

<u>Dallas Peterson, Donn Shilling Meetings on Capitol Hill.</u> On Dec. 3 - 4, Dallas and Donn joined me for meetings on the Hill with Kansas and Georgia Senate Offices regarding funding for AFRI grants and "Capacity" programs, WOTUS/NPDES fixes, and the current state of milkweed research. We also had a strategy meeting with Rep. Gabbard's office on moving the AIPM bill forward.

<u>Herbicide Resistance Education</u>- Excellent work on www.TakeActiononWeeds.com. Lots of work and review by weed scientists. We need to promote the site. In December, David Shaw gave a presentation at the House Ag Committee titled: "Battling the Wicked Problem of Herbicide Resistance: The Human Dimensions of Herbicide Resistance Evolution". About 60 Capitol Hill staffers attended. Closing comments were provided by WSSA president Dallas Peterson. WSSA's Herbicide Resistance Education Committee is proposing regional stakeholder workshops for herbicide resistance management to be held around the country in Fall 2016, with the progression towards a 3rd Herbicide Resistance Summit in Washington DC in Fall 2017.

<u>Foundation for Food and Agriculture Research (FFAR)</u>. – Provided weed research recommendations to the FFAR Board of Directors on Oct 30 during their first public stakeholder meeting. FFAR is a new non-profit Foundation that will leverage public and private resources to increase the scientific and technological research, innovation, and partnerships critical to boosting America's ag economy. Congress authorized up to $200 million which must be matched by non-federal funds as the Foundation identifies and approves projects. *The majority of weed science* *research funding comes from* ***non-federal sources.*** Weed scientists can leverage FFAR funds to help solve pressing agricultural challenges like pollinator and monarch butterfly protection, biofuels production, herbicide resistance, and areawide, aquatic, and organic weed control.

Concerns on EPA Changes to Certification and Training rule. EPA is revising the training requirements for pesticide applicators. The draft offered for public comment would approximately double the training hours required for certification. Such requirements would not only expand the time applicators would need to spend to acquire or maintain their licenses, but the changes will have significant costs and impacts on state lead agencies, university extension programs, and the applicators subject to regulatory certification. Full Rule Proposal – Pesticides: Certification of Pesticide Applicators.

WOTUS- Congress Doesn't Have 2/3rds Majority to Repeal

The majority of the House and Senate supported legislation (HR 1732; S. 1140) that would have forced the Obama administration to rewrite the controversial Clean Water Act rule that expanded "Waters of the United States (WOTUS). However, neither chamber had the necessary 2/3's majority needed to override an Obama veto. The EPA and Army Corps of Engineer's WOTUS rule also survived a proposed roll-back in the FY 2016 Omnibus spending bill passed in December, despite the Government Accountability Office's (GAO) finding that: "*The Environmental Protection Agency (EPA) violated publicity or propaganda and anti-lobbying provisions contained in appropriations acts with its use of certain social media platforms in association with its "Waters of the United States" rulemaking in fiscal years 2014 and 2015.*" See: http://www.gao.gov/products/B-326944. Meanwhile, the Sixth U.S. Court of Appeals just ruled that a federal appeals court rather than a district court was the proper venue to hear challenges to the rule clarifying regulatory reach of the Clean Water Act. The decision affects the 20 challenges to the clean water rule that are consolidated in the Sixth Circuit and an additional 13 challenges that also have been in a holding pattern in federal district courts awaiting the Sixth Circuit's decision. Now the American Farm Bureau Federation and other industry groups will likely petition the full Sixth Circuit to rehear the question of venue because they supported review at the district courts.

NPDES Fix Possible as Part of Bipartisan Sportsmen's Bills

Last year the House Agriculture Committee passed The Reducing Regulatory Burdens Act of 2015 (H.R. 897). This legislation had passed the House in two previous sessions of Congress but failed to get floor consideration in the Senate. H.R. 897 clarifies Congressional intent and eliminates the duplicate regulatory requirement of a National Pollutant Discharge Elimination System (NPDES) permit for the use of herbicides in, over, or near waters of the United States that are already approved for use under FIFRA. In the Senate, Crapo (R-ID) and McCaskill (D-MO), along with 14 other Senate Co-sponsors, introduced S. 1500 as a companion bill to H.R. 897, but it has not gotten a vote on the Senate floor. However, S. 1500 was offered and accepted as an amendment to the long awaited “Bipartisan Sportsmen’s Act of 2016” (S. 659) by the Senate Environment Public Works (EPW) Committee on Jan. 20. S.659 is expected to get action on the Senate floor in March. Similar legislation in the House called the “Sportsmen’s Heritage and Recreational Enhancement Act of 2015” (SHARE Act, H.R. 2406) was passed on Feb. 26 by a 242-161 vote. In the meantime, EPA is proposing a new 5 year NPDES permit because the original one expires on Oct. 1, 2016. Comments are due on March 7.

NISC/ISAC: The National Invasive Species Council (NISC) has a new executive directive, Dr. Jamie Reaser. NISC remains under fire from Congress and there were calls at a Dec. 1 hearing to disband NISC. Their 3rd invasive species management plan is expected this spring. While I continue to serve as co-organizer for NISAW, NISC has decided to withdraw from their co-organizer role. Taking their place is Scott Cameron, president of the Reduce Risks from Invasive Species Coalition (RRISC). Finally, WSSA nominated Jacob Barney and Rob Richardson for the Invasive Species Advisory Committee (ISAC).

NISAW- Was Feb. 21-27, 2016. See www.nisaw.org for many recorded webinars during the week, including a presentation by Jacob Barney on a CAST issue paper: **A Life-cycle Approach to Low-invasion Potential Bioenergy Production**. NISAW concluded with a Congressional Reception and Fair on Capitol Hill were many of the Federal Agencies presented information and educational materials on their invasive species activities. Welcoming remarks were given by Congressional Invasive Species Caucus Co-Chairs, Reps. Dan Benishek (R-MI) and Mike Thompson (D-CA), in addition to remarks by Rep. Cynthia Lummis (R-WY). The keynote address was given by the Administrator of USDA-APHIS, Kevin Shea.

Canada, European Union- Glyphosate Unlikely to Cause Cancer in Humans

The IARC review of glyphosate has been challenged by many due to a lack of transparency, selective inclusion or exclusion of studies, and broad interpretation of study results that are inconsistent with the conclusions of the study authors. Of more than 900 items IARC has reviewed, including coffee, sunlight and night shift work, they have found ONLY ONE (a material in yoga pants) ‘probably’ does not cause cancer, according to their classification system. In November, the very cautious European Food Safety Authority (EFSA) concluded that glyphosate is unlikely to cause cancer in humans. The Canadian Pest Management Regulatory Agency (PMRA) also concluded that “the overall weight of evidence indicates that glyphosate is unlikely to pose a human cancer risk.” The EPA is expected to release their findings on glyphosate’s registration review sometime soon.

Glyphosate Not Found in Breast Milk -Results of a study commissioned by the German Federal Institute for Risk Assessment (BfR) in which renowned research laboratories in Europe developed two independent analytical methods with high sensitivity to test 114 breast milk samples showed that none of the analyzed samples contained glyphosate residues. The study results were published in the January 25, 2016 issue of the Journal of Agricultural and Food Chemistry and supports the EU plan to renew a 15-year license for glyphosate. The EU representatives will vote on the glyphosate relicensing this week in Brussels, Belgium.

APHIS BRS updating Biotech Regulations

APHIS has prepared a programmatic environmental impact statement (EIS) in connection with potential changes to the regulations regarding the importation, interstate movement, and environmental release of certain genetically engineered organisms. See http://www.regulations.gov/#!docketDetail;D=APHIS-2014-0054 The notice identifies reasonable alternatives and potential issues to be evaluated in the EIS and requests public comments to further define the scope of the alternatives and environmental impacts and issues for APHIS to consider. We will likely be commenting on this. Comments are due April 21, 2016.

EPA will issue a Proposed Rule for Herbicide Resistance Stewardship – stay tuned. The National and Regional Weed Science Societies will be doing considerable work on this.

Monarch Butterfly Numbers are Up- 1.13 ha to 4.01 ha in Mexico's oyamel fir forest. However, we will continue to work on improving monarch butterfly habitat and pollinator habitat in general.

Industry Unrest and Employment Outlook. Terry Crawford*; New Mexico State University, Las Cruces, NM (070)

Economic activity, predicted by OECD, is expected to expand at less than two percent for the U.S. in 2016 and 2.2 percent in 2017, with a corresponding slower job growth as the U.S. approaches full employment. World economy growth is expected to be three percent in 2016 down substantially from last year. Growth in the World economy is expected to be volatile, given Central Banks monetary policies with negative interest rates, Chinese economic uncertainties, and falling commodity prices. Lower crop prices in the near term will result in declines in planted acreage according to USDA baseline forecast for 2016 to 2025, with increasing yields providing most of the gains in U.S. crop production. Both net cash and net farm income are forecast to decline for the third consecutive year after reaching recent highs for net farm income and for net cash income. Net cash farm income is expected to fall by two and a half percent in 2016, while net farm income is forecast to decline by three percent. Mergers and acquisition activities (M&A) will slow in 2016 as economic uncertainty clouds the market outlook. Firms previously looked to solidify market share taking advantage of excess monetary supply. Monetary liquidity found its way into the stock market to enhance firms M&A activities. Job growth in food and agriculture for college graduates is expected to grow 58,000 per year from 2015 to 2020 with 28,700 in management and business, as job growth may exceed available college graduates in agricultural related fields.

Medicinal Plants of the US Southwest. Mary A. O'Connell*; New Mexico State University, Las Cruces, NM (071)

Many people living in the southwestern region of the United States actively wildcraft medicinal plants. Extracts prepared from these plants are used for a wide range of health conditions, however, many of these plants have never been characterized to determine their chemical composition or identify candidate bioactive compounds. Using the ethnobotanical literature as a guide, specific medicinal plants are characterized in detail to identify new and promising drug leads. Furthermore, variation in chemical composition of the bioactive components in these plants is expected due to both genetic differences in the populations of these plants and environmental effects during the growth of the plants. Population analysis of medicinal plants is also necessary to compare and characterize optimal sources of these medicinal plants.

Yerba mansa (*Anemopsis californica* (Nutt.) Hook. & Arn.) is one of the most widely used medicinal plants with a native range from California through western Texas. Three distinct chemotypes were detected using a hierarchical clustering analysis on the concentration of 10 different analytes (a-pinene, 1,8-cineole, myrtenol, methyleugenol, isoeugenol, elemicin, piperitone, limonene, and cymene) in three individuals from each of 17 populations. These differences in composition suggest a role for human selection and use of distinct populations of this plant for specific health applications. The essential oil from yerba mansa rhizome inhibited the growth of AN3CA (uterine cancer) and HeLa (cervical cancer) cells in vitro but had no inhibitory activity against lung, breast, prostate or colon cancer cells. The IC_{50} values for the root oil were 0.056% and 0.052% (v/v) for the AN3CA and HeLa cells, respectively. A second regional plant, *Datura inoxia* (Mill.) in the nightshade family, was also investigated for anti-cancer potential. Plants in this family and specifically the *Datura* genus are an important source of tropane alkaloids. Methanolic extracts of leaves were generated and a novel withanolide class compound, Dinoxin B, was purified. This compound was unique to *D. inoxia* and accumulated primarily in leaves. The IC_{50} values for Dinoxin B against human breast cancer cell lines were sub-micromolar.

The flora of the American Southwest is an underdeveloped source of medicinal plants. New anti-microbial drugs as well as new anti-cancer drug leads are likely to be detected. The current and active role of regional people in collecting and using these plants is a distinct advantage for the selection of specific populations and species of useful plants in biomedical research.

PROJECT 1: WEEDS OF RANGE AND NATURAL AREAS

Timing Considerations for Optimal Herbicide Control of Mesquite in the Arid Southwest. Kirk McDaniel*; New Mexico State Univ., Lasw Cruces, NM (098)

Abstract not available

Ecology and Current Management of Saltcedar and Russian Olive in Arizona. John H. Brock*; Brock Habitat Restoration and Invasive Plant Management, Tempe, AZ (099)

Saltcedar (*Tamarix ramosissima* Ledeb.) and Russian olive (*Elaeagnus angustifolia* L.) are alien invasive woody plants that occupy many streams and wetlands in Arizona. Saltcedar is present in over most of the state and Russian olive is found in the northern part of the state on the Colorado Plateau. Both species were introduced as ornamentals, and/or for stream bank stabilization. Past cultural management aided their spread and establishment. Both species are considered to be phraetophytes and provide inferior habitat quality compared to native vegetation. Further they transform the riparian area to poor watershed quality. The ecology of both species will be presented in a compare and contrast fashion. Impacts of these species to the invaded landscapes will be discussed. Management for these species can be placed in an integrated pest management (IPM) program. Current vegetation management techniques, such as changes in cultural practices, mechanical, chemical, fire and biological treatments will be discussed. Mechanical treatments can promote vegetative regeneration as does prescribed or wild fires. Chemical treatments can be applied as cut-stump, basal bark, or foliage sprays. Best management practices for each treatment will be presented. Recently, biological control with the release of a beetle targeting saltcedar has been showing promise as part of an IPM approach for its control. Restoring properly functioning riparian habitats is a worthy goal and vegetation management of these species can provide better water yield from treated sites.

Efficacy and Timing of Low-Rate Herbicide Applications to Herb Robert (Geranium robertianum) in Pacific Northwest Forest Habitat. Timothy W. Miller*; Washington State University, Mount Vernon, WA (100)

Herb robert (*Geranium robertianum*) is spreading exponentially in the Pacific Northwest, prompting its listing as a noxious weed in Washington and Oregon. Most herb robert infestations grow comingled with populations of native perennial plant species, so herbicides were applied at a dosage previously shown to control seedling/young herb robert plants to determine the effect of these low rates on established native plants. Trials were established in late- and early-seral forests at Olympic National Park (ONP) and North Cascades National Park (NCNP), respectively, during 2015. The most frequently occurring native species at ONP were red alder (77% of plots), Pacific blackberry (77%), sword fern (95%), bigleaf maple (55%), mitella (66%), and salmonberry (55%); most frequent species at NCNP were Pacific blackberry (63%), bracken fern (50%), Oregon grape (45%), sword fern (42%), and salal (42%). The most frequent non-native species were catchweed bedstraw (83 and 23%, at ONP and NCNP, respectively) and wall lettuce (27% at both sites). Herb Robert occurred in 44% of plots at ONP. Low rates of glyphosate (0.75%), imazapyr (0.5%), sulfometuron (1 oz/a), and aminopyralid (3 fl.oz/a) were applied in early May, mid-July, and late September, and full rates of 20% acetic acid, clove oil (20%), and limonene (12.5%) were applied at all three timings. In late September, herb Robert control was 95% with glyphosate applied in July and 90% with sulfometuron applied in May or limonene applied twice (May and July). Control with imazapyr was 80 and 85% when applied in May and September, respectively. Native species showing greater than 30% injury at two or more evaluations included red alder (from glyphosate and sulfometuron), salmonberry (glyphosate, imazapyr, and sulfometuron), grass/sedge species (glyphosate and imazapyr), spring beauty (glyphosate and aminopyralid), thimbleberry (glyphosate, imazapyr, and aminopyralid), and mitella (glyphosate). Thimbleberry was also sensitive to acetic acid and clove oil, salmonberry to limonene, and salal to clove oil. Additional evaluations will be made in spring/summer of 2016 to determine the longevity of herb Robert control and whether native plant injury was transitory or permanent.

Effects of Scotch broom removal on resource availability and plant community characteristics in Douglas-fir plantations. Timothy B. Harrington*[1], Robert A. Slesak[2], David H. Peter[1], Anthony W. D'Amato[3];[1]USDA Forest Service, Olympia, WA, [2]University of Minnesota, Minneapolis, MN, [3]University of Vermont, Burlington, VT (101)

Scotch broom (*Cytisus scoparius*) is a nonnative, leguminous shrub that competes vigorously with planted Douglas-fir seedlings and associated vegetation for site resources and growing space. To determine if removal of Scotch broom restores ecological functions of native plant communities, we quantified short-term changes in resource availability and plant community structure and composition. In October 2013, studies were initiated in two 10-year-old Douglas-fir plantations near Matlock, WA and Molalla, OR where Scotch broom had established in 2004 or 2005. The experimental unit was a 2- x 2-m measurement plot centered within a 3-m radius circular treatment plot. Ten replications per treatment (i.e., Scotch broom removed or retained) were installed at each site as a completely randomized design. Scotch broom was removed by severing the stems at 30 cm height and carefully applying a basal spray of a 20% solution of Garlon® 4 (triclopyr ester) in an oil carrier to avoid contact with other plant species. Beginning in early 2014, readings of soil water content at 30 cm depth (via Decagon Devices, Inc., EC-5 sensors) and soil temperature at 5 cm depth (via Maxim Integrated, Ibutton® sensors) were logged periodically for each plot. In late June 2015, photosynthetically active radiation (PAR) at 50 cm height was measured in each plot with an AccuPar® ceptometer (Decagon Devices, Inc.). During the summers of 2014 and 2015, cover of each plant species was estimated visually within each plot. Soil water content was greater where Scotch broom was removed than where it was retained but differences were statistically significant only in 2014, the first year after treatment. Soil temperature in 2014 and 2015 and PAR in 2015 were also greater where Scotch broom had been removed. Scotch broom removal was associated with increased abundance of four nonnative herbaceous species and decreased abundance of four native woody species. Reduced abundance of native woody vegetation following Scotch broom removal was attributed to collateral damage associated with the treatment (i.e., physical damage to vines of *Rubus ursinus* during removal of Scotch broom stems and ice damage to the recently-exposed stems of *Frangula purshiana*). Although soil water availability increased following Scotch broom removal, the response lasted only one year as nonnative herbs occupied the newly available growing space. The observed secondary invasion by nonnative herbaceous species suggests that either more recovery time or additional treatments may be needed to restore ecological functions of the native plant community.

Invasive Pine Trees in Hawaiian Natural Areas. A Briefing on Current Experimental Treatments. Jeremy Gooding*[1], James K. Leary[2], Stacey K. Torigoe[3]; [1]National Park Service, Pukalani, HI, [2]University of Hawaii, Kula, HI, [3]Haleakala National Park, Kula, HI (102)

Paper withdrawn

An Integrated Telemetry System for Herbicide Ballistic Technology (HBT) to Determine Dose To Target and Area Use Rate. Roberto Rodriguez*[1], James Leary[2], Daniel Jenkins[1]; [1]University of Hawaii, Honolulu, HI, [2]University of Hawaii, Kula, HI (103)

Since 2012, the Herbicide Ballistic Technology (HBT) platform has been deployed in helicopter operations with a mission to eliminate nascent populations of the invasive plant species Miconia (*Miconia calvescens* DC) spreading across the East Maui Watershed (Hawaii, USA). The HBT platform is a refined pesticide application system that pneumatically delivers 0.68 caliber encapsulated herbicide projectiles from long range (up to ~30 m) and varying attitude. This onboard system provides accurate, effective treatment of individual plant targets occupying remote, inaccessible portions of the forested landscape. Operational performance is characterized through GIS analyses of recorded GPS data assigned to treated plant targets. A telemetry system for HBT applications (HBT-TS) was developed to increase data acquisition by providing time stamped, geo-referenced attribute data for every projectile discharged including, (i) target assignment, (ii) azimuth, (iii) tilt and (iv) range determined from the applicator position in the aircraft. With target assignments, the HBT-TS records the estimated dose applied to each target. By tracking the orientation and distance of each discharged projectile, we are able to calculate a precise offset target location relative to the applicator position and provide a more accurate interpretation of herbicide use rate (grams acid equivalents ha^{-1}), simply based on the known amount of herbicide contained in each projectile, i.e., 200 mg Triclopyr, and placement on the landscape. Furthermore, the projectile timestamps show that actual time to administer target treatment is a minor component of the total time on target. This technology demonstrates how high-resolution data management allows for interpretation of a discrete, yet effective, herbicide use pattern in invasive plant species management.

Why Does it Take Federal Agencies So Long to Start Treating Their Weeds? Shawna L. Bautista*; US Forest Service, Portland, OR (104)

When planning weed management activities, it can be frustrating to be a partner or neighbor of a federal land management agency. Federal agencies can be slow to implement weed treatments and adopt the newest chemistries. Among the many reasons for delayed implementation, but two primary considerations unique to federal agencies are implementing regulations for 1) the National Environmental Policy Act (NEPA) and 2) the Endangered Species Act (ESA). NEPA requires that environmental information be made available to public officials and citizens before decisions are made and actions are taken. This requirement applies at multiple scales, which can result in several "layers" of NEPA documents, analyses, and procedures. Additionally, each agency has objection and litigation procedures when groups or citizens disagree with the decision made. Similarly, all Federal agencies are required to ensure that their actions do not harm species listed under the Endangered Species Act. If federally listed species or their habitat are located within a project area, proposals to use herbicides within Federal lands require consultation with US Fish and Wildlife Service and/or National Marine Fisheries Service. When herbicide use is included in weed management project proposals, the analyses required to comply with NEPA and ESA are complex and can be controversial. The goal of this presentation is to increase scientists' understanding of the challenges faced by federal land managers and explore possible solutions to increase efficiency.

Prairie Response to Canada Thistle Infestation. Travis R. Carter*, Rodney G. Lym; North Dakota State University, Fargo, ND (105)

Forage response to Canada thistle [*Cirsium arvense* (L.) Scop.] was evaluated in two separate studies. Change in forage following a herbicide application to control Canada thistle was determined using a randomized complete block arrangement with blocks divided into two subplots (treated and control), and replicated 12 times at two locations. Aminopyralid at 120 g ha^{-1} was applied June 2015 and forage was harvested 1 and 13 months after treatment, dried, and weighed. The only increase in forage production was observed at Fargo in 2015. Forage increased from 1920 to 2240 kg ha^{-1} 1 yr after aminopyralid reduced Canada thistle density from 14.8 stems m^{-2} in the control to 2.9 stems m^{-2}. Based on North Dakota hay price, the cost of aminopyralid, and herbicide efficacy, the economic threshold for Canada thistle control was approximately 37 stems m^{-2}. Forage production was also estimated at 20 wildland sites using a paired-plot design, with three subplots inside and three outside a Canada thistle infestation. Forage was harvested in July 2015. Production was similar between Canada thistle infested and non-infested sites in North Dakota. Thus, control efforts would rarely have a positive economic return since the only increase in production required an extremely high density of Canada thistle. However, control of Canada thistle can improve hay palatability and the growth and abundance of desirable species.

Drawdown Applications for Control of Flowering Rush. John D. Madsen*[1], Kurt D. Getsinger[2], Thomas E. Woolf[3], Brad Bluemer[4]; [1]USDA ARS, Davis, CA, [2]US Army Engineer Research and Development Center, Vicksburg, MS, [3]Idaho State Department of Agriculture, Couer D'Alene, ID, [4]Bonner County Public Works Department, Sandpoint, ID (106)

Flowering rush (*Butomus umbellatus* L.) is an invasive weed to shallow water and moist soil environments. In the West, it is spreading primarily in Washington, Idaho, and Montana along the Flathead, Clark Fork, Pend Oreille, and Columbia River systems, with scattered populations elsewhere in this region. Since the plant grows well in shallow water (up to 4 m deep) to moist soil environments, it thrives well in western reservoirs that experience significant water level fluctuations. For this species, multiple herbicide use patterns and an assortment of products will be needed to manage the plant in a variety of habitats, and under a wide range of regulatory restrictions due to federal and state herbicide restrictions, including endangered species issues. In this study, we evaluated the use several herbicides on moist soil sites of a scheduled drawdown in

Pend Oreille Lake, Idaho. Fifteen plots (0.1ha) were established at the Clark Fork River delta, with three replicates each of four treatments and an untreated reference. The treatments included imazapyr (5.6 L/ha), with and without the addition of 2,4-D (1.8 L/ha); and imazamox (2.8 L/ha), with and without the addition of 2,4-D (1.8 L/ha). All treatments also received 2.8 L/ha of a nonionic surfactant. The herbicides were applied by ATV prior to predicted rain, just after the emergence of new flowering rush growth in the spring (late April). Plots were evaluated using both estimated percent cover, and with ten biomass samples per plot using a 0.18 m^2 core sampler. Biomass samples were sorted to rhizomes and shoots, and the number of rhizome buds was counted. Samples were taken before treatment in March, and at 12 weeks after treatment. By 12 WAT, imazamox or imazapyr treatments alone significantly reduced aboveground biomass. The addition of 2,4-D did not enhance the treatments with either imazamox or imazapyr. We plan to further evaluate these treatments at 52 and 66 WAT.

Effects of Musk Thistle Management on Forage Quality in Montane Rangelands. John B. Coyle*, Scott J. Nissen, Paul Meiman; Colorado State University, Fort Collins, CO (107)

Typical musk thistle (*Carduus nutans*) infestations are associated with highly disturbed lands; however, encroachment into the otherwise healthy montane range is being observed on Colorado's Western Slope. We hypothesize that treating these musk thistle infestations using selective herbicides at lower dose rates would not impact overall forage quality or overall species abundance. In fall of 2014, four post emergent herbicide treatments (85.3g/ha and 198.9g/ha of aminopyralid, 273.3g/ha picloram, and 138.9g/ha aminocyclopyrachlor + 55.3g/ha chlorsulfuron) and a non-treated control were applied in a split-plot design. Plots were 7 by 30 meters with 3 replications per herbicide treatment located on two research sites. Cover data and above ground biomass were collected to evaluate treatment effects 12 months after treatment (MAT) and the forage component was sent for feed analysis. The four herbicide treatments reduced musk thistle cover an average of 91.6% ± 2.7 SE with no significant differences in musk thistle control observed between herbicides. Species abundance was not significantly different between herbicide treatments and control. Finally, the feed analysis found that while the aminocyclopyrachor + chlorsulfuron treatment resulted in reduced Total Digestible Nutrients (TDN) of the forb component there is no significant reduction in the overall feed values when total biomass (grass + forbs) is taken into account. Results demonstrate that musk thistle can effectively be controlled, while at the same time preserving forage quality and, ultimately, production. These results indicate a prescription for the infestation but further research will be needed to explain why the infestation is occurring.

Beweeded History. Saleh Dadjouy*; Colorado State University, Fort Collins, CO (123)

Paper withdrawn

Inventory of Multiple Weed Species Using Helmet Based Video. Corey V. Ransom*, Heather E. Olsen; Utah State University, Logan, UT (124)

Invasive plant inventories are a valuable resource in planning and carrying out a strategic weed management plan. Considering the expense involved in collecting species distribution data, trials were initiated and reported on in 2014 looking at the possibility of creating weed distribution maps using helmet mounted video cameras and using the video to generate maps at a later time. In 2015, additional tests were conducted to evaluate this mapping technique in comparison to on-the-ground mappers recording infestations on handheld GPS units. Methods were similar to 2014. The video-based approach utilized an individual riding a mountain bike. The rider wore a helmet with two video cameras (GoPro Hero3+ and Hero4, GoPro Inc.) mounted using 3-axis gimbals to reduce camera movement and provide stable video. Cameras faced approximately 70 degrees apart to provide an extreme wide-angle view. A tracklog corresponding to the video footage was collected using a smart phone. The videos from both cameras were blended into a single video (Premiere CS6, Adobe) and then imported along with the corresponding tracklog into a software (VIRB Edit, Garmin Ltd.) that allows the video and the tracklog to play simultaneously. Using a second computer monitor, infestation shapes were drawn onto a GIS map (ArcPad 10, ESRI) as they were observed in the video. The time spent mapping on the computer was recorded and was added to the time required to ride each trail section to determine total time required for mapping. Comparison of the two mapping methods included total time, total number of points, polygons, and lines, as well as species detected and total infested acres. Six trails were mapped using both approaches in 2015. In general, these trails were more forested and had denser vegetative cover compared to the trails mapped in 2014. On three of the trails (Richards Hollow, Rick's Canyon, and Spring Hollow), only dyer's woad in full bloom was mapped during the first week of June. The other three trails (Green Canyon, Blind Hollow, and Providence Canyon) were mapped for all invasive weed species with two trails mapped in late July and the other on September 4. Trails mapped only for dyer's woad were 4.1 to 5.8 miles in length, while those mapped for all species ranged from 2.6 to 3.8 miles long. In these studies, all trails were mapped from the top down. Similar to previous trials, the video based method was more time efficient compared to mapping on foot with time savings of 47 to 69%. However, on-the-ground mapping resulted in more infestation features, and acreage estimates were 2 to 15 time greater than for the video method for visible species. Canada thistle and houndstongue, and dyer's woad that had gone to seed, were not discernable from the videos. In many instances, polygons for dyer's woad and poison hemlock were in the correct location and differences in recorded infestation size may have been related to the subjectivity in drawing the infestation polygons. At some locations, the on-the-ground mappers were able to detect an infestation on a hillside that was not in the view of the video cameras. Burdock results were variable, being detected in the video in open understory, but not when mixed with other vegetation. The video approach has promise for plants with distinctive color or unique architecture in open terrain, but has limited utility for mapping plants in the rosette stage surrounded by dense vegetation.

Leafy Spurge Control in Environmentally Sensitive Areas with Quinclorac. Rodney G. Lym*; North Dakota State University, Fargo, ND (125)

The use of quinclorac to control leafy spurge was initially developed in the 1990s but was little utilized until a full grazing label was obtained in 2010. Quinclorac has the desirable trait of a narrow activity spectrum. For instance, in a six-state regional trial, quinclorac applied to control leafy spurge did not injure lead plant (*Amorpha canescens* Pursh), purple prairie clover (*Dalea purpurea* Vent.), or red clover (*Trifolium pratense* L.) in Nebraska; prairie wild rose (*Rosa arkansana* Porter), sandbar willow (*Salix interior* Rowlee), or anemone (*Anemone* spp.) in North Dakota; nor wild raspberry (*Rubus* spp.) in Minnesota. Quinclorac did not harm the endangered species western prairie fringed orchid (*Platanthera praeclara* Sheviak and Bowles) as plants treated with quinclorac regrew as vigorously and were as fecund as untreated orchids. While control of leafy spurge with quinclorac has been well documented, the ideal leafy spurge growth stage for treatment was unclear. The purpose of this research was to determine the optimum application timing for leafy spurge control with quinclorac. Quinclorac was applied at 6, 9, or 12 oz/A alone or with dicamba plus diflufenzopyr or 2,4-D and was compared to aminocyclopyrachlor plus chlorsulfuron at two locations in North Dakota. Both locations were within grazed pastures with a dense stand of leafy spurge. Treatments were applied in June or September 2014. Quinclorac provided better long-term leafy spurge control when applied in June compared to September. For instance, leafy spurge control averaged across all quinclorac application rates was 87 and 57% 12 months after treatment (MAT) when applied in June or September, respectively. Quinclorac applied in September 2014 provided excellent control when evaluated in June 2015 (96% average) but control dropped rapidly at both locations by 12 MAT. Leafy spurge control tended to increase as the quinclorac application rate increased with 9 oz/A (81% control 12 MAT) the most likely cost-effective application rate considering both long-term control and chemical cost. Leafy spurge control tended to be higher when quinclorac was applied alone compared to application with dicamba plus diflufenzopyr or 2,4-D.

Leafy Spurge (Euphorbia esula) Control in Sensitive Sites with Aminopyralid Products.
Vanelle F. Peterson*[1], Celestine Duncan[2], Rodney G. Lym[3], Scott J. Nissen[4]; [1]Dow AgroSciences, Fort Collins, CO, [2]Weed Management Services, Helena, MT, [3]North Dakota State University, Fargo, ND, [4]Colorado State University, Fort Collins, CO (126)

Aminopyralid products such as aminopyralid (Milestone® herbicide, 2 lb ae/gal) and aminopyralid + 2,4-D amine (GrazonNext®/ ForeFront® HL herbicides, 0.41 + 3.33 lb ae/gal) are registered for use on range and pasture and non-cropland sites to control many broadleaf noxious and invasive weeds. Aminopyralid products are useful tools in sensitive sites such as under and around non-sensitive trees and around water with label directions allowing use "up to the water's edge". Previous research has shown that (1) aminopyralid has activity on leafy spurge, a hard to control perennial noxious weed, but control is not commercially acceptable at labeled rates, and (2) the addition of dicamba + diflufenzopyr (OverDrive®) to other herbicides can increase leafy spurge control. This research was conducted to determine whether the addition of dicamba + diflufenzopyr to aminopyralid-containing products would improve leafy spurge control. Trials were established near Wellington, CO; Drummond, MT; and Walcott, ND to determine the efficacy of aminopyralid (1.75 and 2.5 oz ae/A) and aminopyralid + 2,4-D (1.75 oz + 14 oz ae/A) for control of leafy spurge alone and with the addition of dicamba + diflufenzopyr (2 oz + 0.8 oz ae/A) in comparison with 2,4-D (14 oz ae/A), picloram (8 oz ae/A) (Tordon® 22K herbicide), and aminocyclopyrachlor + chlorsulfuron (0.12 oz + 0.3 oz ai/A) (Perspective®) applied without dicamba + diflufenzopyr. Applications were made in 2014 on June 2, June 12 and June 23 respectively, with CO_2 backpack sprayers at 13.5 or 20 GPA with 4 replications. Evaluations of visual percent control were made in CO and MT at 54 and 68 weeks after treatment (WAT), and at 50 WAT in ND. At 50 to 54 WAT, the addition of dicamba + diflufenzopyr to aminopyralid + 2,4-D improved leafy spurge control over the product alone (from 81 to 94%). Dicamba + diflufenzopyr applied with aminopyralid at 1.75 and 2.5 oz/A improved control from 27 to 79% and 48 to 83%, respectively, and when applied with aminopyralid + 2,4-D control improved from 68 to 91%. Dicamba + diflufenzopyr provided only 18% leafy spurge control when applied without aminopyralid or aminopyralid + 2,4-D . Picloram and aminocyclopyrachlor + chlorsulfuron gave equal leafy spurge control (98 and 99%, respectively). By 68 WAT leafy spurge control with aminopyralid and aminopyralid + 2,4-D with and without dicamba + diflufenzopyr declined, more so for the aminopyralid and aminopyralid combined with dicamba + diflufenzopyr than when 2,4-D was mixed with aminopyralid. The addition of 2,4-D with aminopyralid increased leafy spurge control when used both with or without dicamba + diflufenzopyr. Control was optimal when aminopyralid + 2,4-D was combined with dicamba + diflufenzopyr. For leafy purge control in sensitive sites land managers could use aminopyralid + 2,4-D alone or aminopyralid + 2,4-D in combination with dicamba + diflufenzopyr. ®™Trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow. ® Trademarks of BASF Corporation, OverDrive, or Bayer Crop Science LP, Perspective.

Changing the Landscape in Western North Dakota with *Aphthona spp.* Flea Beetles. Blake M. Thilmony*, Rodney G. Lym; North Dakota State University, Fargo, ND (127)

Aphthona spp. flea beetles were released in two ecological sites of the Little Missouri National Grasslands in western North Dakota in 1999 for leafy spurge (*Euphorbia esula* L.) biological control. The change in leafy spurge density and soil seedbank composition was monitored to evaluate the effectiveness of the insects on weed control and associated changes in plant communities in upland and lowland sites 5, 10 and 15 yr after release. In 2014, 15 yr after release, leafy spurge stem density decreased 94% from 78 to 9 stems m^{-2} in the upland sites and 89% from 110 to 7 stems m^{-2} in the lowland sites. Leafy spurge represented nearly 70% and 67% of the upland and lowland seedbanks in 1999, respectively, compared to only 6% and 2% in 2014. As leafy spurge abundance declined, Kentucky bluegrass (*Poa pratensis* L.) increased from 8 to 36% and from 21% to 26% in the upland and lowland sites, respectively. The reduced competition from leafy spurge allowed Kentucky bluegrass to invade and become a dominant species. However, the production of Kentucky bluegrass, especially in the loamy overflow sites, has been deterred by a slow shift and reintroduction of native species into the seedbank through the last 5 yr. Native species richness increased from 32 and 31 species in 1999 to 45 and 65 species in 2014 in the upland and lowland sites, respectively. *Aphthona* spp. successfully controlled leafy spurge for over 15 yr without any additional control methods or costs to land managers.

Evaluation of New Herbicides for Dalmatian Toadflax Control. Julia M. Workman*[1], Brian A. Mealor[2]; [1]University of Wyoming, Laramie, WY, [2]University of Wyoming, Sheridan, WY (147)

Dalmatian toadflax (*Linaria dalmatica* [L.] Mill.) is an invasive weed of northeastern and western North American rangelands known for displacing desirable communities and reducing forage, particularly following disturbance. Managers typically use herbicides to manage toadflax populations and prevent its spread. This experiment was designed to complement a separate study comparing herbicide with targeted sheep grazing. Our objective was to evaluate Dalmatian toadflax control with four herbicides alone and in combination, at the same rates, applied in either fall or spring at two sites. We applied herbicides in late fall 2013 and late spring 2014. Fall treatments generally reduced toadflax cover more than spring treatments in 2014 ($p < 0.0001$). In midsummer 2015, 21 months after treatment (MAT; fall application) and 13 MAT (spring application), chlorsulfuron+aminopyralid and treatments containing aminocyclopyrachlor most reduced toadflax biomass at site 1 ($p = 0.0024$). Fall treatments, irrespective of herbicide, reduced toadflax density and increased perennial grass biomass compared to spring treatments ($p < 0.03$). Treatments containing aminopyralid resulted in the greatest perennial grass biomass, particularly when applied in the fall ($p < 0.0001$). Managers should consider recovery potential of an invaded site prior to vegetation treatments. Where perennial grass recovery is likely, fall treatments may provide most consistent toadflax control with the least desirable species damage. Chlorsulfuron+aminocyclopyrachlor provided the best control in our study while retaining perennial grass biomass similar to the non-treated check, but fall applications of other herbicides may provide acceptable toadflax reduction while increasing perennial grass biomass.

Evaluating Targeted Grazing for Dalmatian Toadflax and Geyer Larkspur Management. Julia M. Workman*[1], Brian A. Mealor[2]; [1]University of Wyoming, Laramie, WY, [2]University of Wyoming, Sheridan, WY (148)

Rangeland weeds are costly pests, reducing forage, adversely affecting livestock, or increasing producers' expenses. Some, like the invasive Dalmatian toadflax (*Linaria dalmatica* [L.] Mill.), are considered noxious throughout the West. In contrast, the native Geyer larkspur (*Delphinium geyeri* Greene) is limited in distribution but associated with spring cattle mortality. Research that evaluates grazing as a management tool for these species is limited and sometimes conflicting. Our objectives were 1) to determine effects of sheep grazing on Dalmatian toadflax, Geyer larkspur, and associated vegetation, and 2) to compare grazing to herbicide treatments. We allowed ewes to graze experimental units at a constant stocking rate, but varied grazing timing and frequency. We also applied two herbicide treatments (metsulfuron and chlorsulfuron+aminocyclopyrachlor) in spring 2014. We measured cover, biomass, and weed density. All grazing treatments initially reduced larkspur density and limited its regrowth in the two months following grazing ($p<0.0015$). However, only herbicide had residual effects on larkspur density in 2015 ($p=0.0001$). More than 80% of toadflax stems were impacted in all 2014 grazing treatments and events, and 45-70% of stems in 2015 treatments ($p<0.0001$). In midsummer 2015, chlorsulfuron+aminocyclopyrachlor provided the best toadflax control, and grazing twice annually appeared to limit toadflax spread better than our other grazing treatments ($p<0.065$). Although all grazing treatments visually impacted perennial grasses, grass biomass production was similar to the check in all but one treatment in midsummer 2015 ($p=0.0476$). Two years may be insufficient time to see impacts of repeated heavy grazing in this study system.

A 20-year Retrospective Evaluation of Seeding Competitive Perennial Grasses for Dalmatian Toadflax Suppression. Beth Fowers*[1], Brian A. Mealor[2]; [1]University of Wyoming, Laramie, WY, [2]University of Wyoming, Sheridan, WY (149)

Weed management studies commonly focus on short term results, often due to practical and logistical constraints. However, the effects of integrated weed management actions may persist over time. As rangeland weed management has moved from primarily a 'weed killing' endeavor toward a systematic approach for reducing weeds and restoring desirable vegetation, a better understanding of the long-term impacts of management is needed. In this project, we focus on Dalmatian toadflax (*Linaria dalmatica*) — a perennial forb introduced to North America in the late 1800's as an ornamental plant. Research in the 1990s indicated that seeding of competitive perennial grasses can provide short-term toadflax suppression. Our objectives were to evaluate plant community composition within a Dalmatian toadflax infestation that had been seeded to various perennial cool-season grasses 20 years ago. In the short-run, picloram (0.5 lb ai · A^{-1}) followed by reseeding of cool-season grasses shifted the site toward significantly more grass and less toadflax. All cool-season grasses seeded in August 1995 reduced Dalmatian toadflax biomass production by more than 70% three years after seeding (1998; $p<0.05$). Thickspike and crested wheatgrasses provided the greatest short-term toadflax reduction (91 and 90%, respectively). By 2015, the spring-seeded grasses showed slight to moderate toadflax reductions whereas toadflax production was markedly higher in the fall-seeded treatments than where no seeding occurred. Pubescent wheatgrass seeded in April 1995 most closely met the long-term goals of decreasing toadflax (-73%) and increasing grass (+163%). Long-term efficacy data of single restoration treatments are limited, but should be interpreted with caution.

Winter Annual Grass Control and Remnant Plant Community Response to Indaziflam and Imazapic. Derek J. Sebastian*, Scott J. Nissen; Colorado State University, Fort Collins, CO (150)

One of the major limitations for invasive winter annual grass control is the lack of consistent long-term control. Downy brome (*Bromus tectorum* L.) and feral rye (*Secale cereale* L.) are two invasive winter annual grass species found throughout the western US. Establishment of these species on rangeland results in significant reductions of desirable perennial grass, forb, and shrub species. Although imazapic, glyphosate, and rimsulfuron are commonly recommended, inconsistent control and non-target injury are commonly observed. Indaziflam, a recently registered cellulose-biosynthesis inhibitor (CBI) herbicide, provides residual activity on annual weeds in established turf demonstrating the potential of indaziflam to control annual weeds such as downy brome on rangeland. Field studies were conducted to compare downy brome and feral rye control with indaziflam to currently recommended herbicides, and evaluate treatment impacts on the desirable remnant plant communities. Indaziflam treatments resulted in a 10 to 16-fold increase in perennial grass biomass 2 YAT and maintained downy brome and feral rye control (95-100%); while, imazapic had a 2 to 4-fold increase in perennial grass biomass 2 YAT, with no impact on downy brome and feral rye biomass. Indaziflam treatments showed no visual injury to the remnant perennial grass, forb, and shrub plant communities. Across multiple sites, indaziflam treatments resulted in superior residual downy brome and feral rye control. The residual downy brome control provided by a single indaziflam application could provide the opportunity to reduce downy brome in the soil seed bank while allowing adequate time for desirable remnant plant communities to re-establish. This research provides the first evidence of a new option for invasive winter annual grass control on rangeland.

PROJECT 2: WEEDS OF HORTICULTURAL CROPS

Biosolarization and Soil Health - A Research Update. James J. Stapleton*[1], Ruth M. Dahlquist[2], Ygal Achmon[3], Jean S. VanderGheynst[4], and Christopher W. Simmons[3]. [1]University of California Kearney Agricultural Center, Parlier, CA; [2]University of California Cooperative Extension, Fresno, CA; [3]University of California, Davis, CA; [4]University of California, Davis, CA (072)

Knowledge-based application of organic materials and soil solarization can be useful, pre-plant treatments to inactivate soil pests, without using synthetic chemical fumigant or nonfumigant pesticides. Biosolarization seeks to improve the pesticidal activity of both approaches, while simultaneously contributing to the overall fertility and microbial richness of the treated soil. With the goal of making biosolarization more effective, predictable, and flexible, we tested mortality of of *Brassica nigra* (black mustard) seeds in heated field soil amended with combinations of mature green waste compost, wheat bran, and/or food processing pomaces, as compared to non-amended field soil. Effects on *B. nigra* seeds were determined by germination and/or tetrazolium vital staining. Mortality of seeds buried in compost-amended soil was significantly higher than in non-amended soil in all trials. Seeds buried at five inch depth in biosolarized plots showed 100% mortality after 3 days of treatment, while those in solarized plots without organic amendment tested at 87% mortality after 22 days of treatment. References: Achmon, et al., *Waste Management* 48:156-164 (2016); Stapleton et al., *CAPCA Adviser* 19(1):24-27 (Feb 2016), online http://capca.com/adviser-magazine/.

Influence of Adjacent Weed Species on Thrips and Iris Yellow Spot Virus in Onion. S. Andrew Swain*, Corey V. Ransom, Diane Alston, Claudia Nischwitz; Utah State University, Logan, UT (073)

Onion thrips (*Thrips tabaci*) and Iris Yellow Spot Virus (IYSV) form a pest-diseases complex of global concern for *Allium* producers. Numerous weed species have been documented as hosts for both onion thrips and IYSV. A study was conducted to explore the relationship between various weed species and pest incidence in onion. Onions were planted in 10 m^2 plots. Treatments were arranged in a randomized complete block design and consisted of 0.7 m wide borders of the following weed species: common mallow, field bindweed, and prickly lettuce. Two additional treatments included borders of resident weed populations, one mowed mid-season. Onion and weed samples were collected four times throughout the season. Plant tissues were tested for virus using ELISA. Counts were used to ascertain thrips adult and larvae numbers. Thrips per gram on onions dipped mid-season but then rose at end of season 2014. Populations declined steadily in 2015. Among the single-species treatments, there were no significant differences in thrips numbers on onions in 2014 or 2015. Thrips increased on onions within the mowed resident weed border treatment compared to the unmowed border treatment in 2014, suggesting thrips migration. This effect was not observed in 2015. Thrips density was higher on field bindweed than other monoculture species at end of season 2014, and was highest on common mallow at beginning of season 2015. Virus incidence was low but was detected in field bindweed, common lambsquarters, hairy nightshade, and witchgrass in 2014, and in all species tested in 2015.

Exploring a Different Method to apply Dimethenamid-p to Control Yellow Nutsedge in Direct-Seeded Dry Bulb Onion. Joel Felix*, Joey Ishida; Oregon State University, Ontario, OR (074)

Yellow nutsedge (*Cyperus esculentus*) continues to be a problem weed of onions in the Treasure Valley of eastern Idaho and southwestern Idaho. Current labels for dimethenamid-p and *s*-metolachlor allow applications to onion starting at the 2-leaf stage. This application timing does not control yellow nutsedge already emerged. We have discovered that application of dimethenamid-p through the irrigation drip starting when onions are at the 2 leaf stage provided better yellow nutsedge control than post emergence (POST) broadcast applications at the same rate. The objectives of this study were to evaluate onion response and yellow nutsedge control when dimethenamid-p solution was injected through the irrigation drip compared to standard POST application at the same rate. The solution containing dimethenamid-p at 580 and 527 g ai ha^{-1} was metered into the irrigation drip sequentially at 2 weeks apart, three weekly sequential injections of dimethenamid-p at 368 g ha^{-1} each, sequential injections of dimethenamid-p at 1,100 g ai ha^{-1} each applied 2 weeks apart, dimethenamid-p at 1,100 g ha^{-1} followed by *s*-metolachlor 1,420 g ai ha^{-1} injected 2 weeks apart, and the grower standard of POST broadcast of dimethenamid-p at 1,100 g ha^{-1}using a small plot prayer. All treatments were initiated when onions were at the 2-leaf stage and yellow nutsedge ranged from not emerged to 4 leaf stage. Onion injury was <5% and transient. Average yellow nutsedge control at 47 days after the last application (DALA) ranged from 70 to 95% for dimethenamid-p applied through the drip compared to 9% for the standard broadcast treatment. Evaluations at 70 DALA indicated 59 to 86% yellow nutsedge control across drip applied treatments compared to 3% for the standard broadcast treatment. Marketable onion yield was similar across treatments ranging from 86 to 103 T ha^{-1} when dimethenamid was applied through the drip compared to 87 T ha^{-1} for the standard treatment. These promising discoveries have been a pleasant surprise because chloroacetamides are not known to control emerged weeds. The study will be repeated in 2016 using multiple varieties.

Effect of Rimsulfuron on Teton Russet Potato Tuber Quality and Yield. Pamela Hutchinson, Brent Beutler*; University of Idaho, Aberdeen, ID (075)

There has been anecdotal evidence that Teton Russet tuber cracking is increased when rimsulfuron is used for weed control with this potato variety. Therefore, field research trials were conducted at two Idaho locations in 2013 and 2014. Rimsulfuron was applied pre- and postemergence at 0, 1, or 2X the labeled rate to Teton Russet and also to Russet Burbank for comparison. In 2013, the postemergence applications caused slight leaf chlorosis and mottling on both varieties due to cool cloudy conditions at application time. Plants grew out of the symptoms and at harvest, regardless of rate, timing, and variety, tuber cracking observed in any herbicide treatment was not different than what was observed with the nontreated control. No foliar injury was observed in 2014, and as in 2013, tuber cracking was not increased by rimsulfuron treatments.

Bicyclopyrone Performance in Minor/Specialty Crops. Stephen M. Schraer*[1], Cheryl L. Dunne[2], Tom H. Beckett[3], Gordon D. Vail[3]; [1]Syngenta Crop Protection, Meridian, ID, [2]Syngenta Crop Protection, Vero Beach, FL, [3]Syngenta Crop Protection, Greensboro, NC (076)

Bicyclopyrone is a newly registered HPPD-inhibiting active ingredient for control of broadleaves and some grasses. Bicyclopyrone is one of the four active ingredients in Acuron herbicide which was registered for sales in corn in 2015. Syngenta is evaluating the potential for expanding bicyclopyrone use into minor/specialty crops where options for weed control are limited. More than 40 crops have been screened in the greenhouse and/or field for pre-emergence and postemergence tolerance to bicyclopyrone. The objective of this presentation is to present data from some of the crops exhibiting acceptable tolerance to bicyclopyrone.

Efficacy and Comparison of Herbicides for Perennial Ryegrass Removal During Spring Transition. Kai Umeda*; University of Arizona, Phoenix, AZ (077)

Spring transition occurs in desert turfgrasses when bermudagrass emerges from winter dormancy and winter overseeded perennial ryegrass declines with the summer heat. The summer heat alone no longer eliminates all of the perennial ryegrass that is bred to withstand higher temperatures. To enable the bermudagrass to re-establish for the summer in a timely manner, herbicides are used to facilitate the selective ryegrass removal. Several ALS enzyme-inhibiting herbicides being used successfully in the desert region include foramsulfuron, trifloxysulfuron, and flazasulfuron. Pronamide, a different mode of action and slower acting herbicide, performs as a transition-aide. Penoxsulam is a newer ALS enzyme-inhibiting herbicide introduced recently as a transition-aide.

Foramsulfuron, trifloxysulfuron, and flazasulfuron significantly affected and reduced ryegrass quality after application in May and then totally eliminated ryegrass by early July. Foramsulfuron also provided nearly complete control of *P. annua* while trifloxysulfuron also gave acceptable control at 88%. Bermudagrass cover was not complete with bare ground observed in foramsulfuron, trifloxysulfuron, and flazasulfuron treated plots. Penoxsulam and pronamide treated ryegrass equally displayed slow rates of ryegrass removal that was less than complete in early July. Both exhibited plots with less bare ground indicating less bermudagrass stunting than that caused by foramsulfuron, trifloxysulfuron, and flazasulfuron. Pronamide only reduced half of the *P. annua* while penoxsulam did not control *P. annua*.

Residual Weed Control Performance of Penoxsulam + Oxyfluorfen in California Tree Nuts.
Byron B. Sleugh[1], Jesse M. Richardson*[2], Rick K. Mann[1], James P. Mueller[1], Alistair H. McKay[3]; [1]Dow AgroSciences, Indianapolis, IN, [2]Dow AgroSciences, Hesperia, CA, [3]Dow AgroSciences, Clovis, CA (078)

Abstract not available

PROJECT 3: WEEDS OF AGRONOMIC CROPS

Comparing Weed Control Treatments in Conventional, Strip, and No-Tillage Sugar Beet.
Don W. Morishita*[1], Kyle Frandsen[2], Samara L. Arthur[2]; [1]University of Idaho, Twin Falls, ID, [2]University of Idaho, Kimberly, ID (079)

With the introduction of glyphosate resistant (GR) sugar beet, weed control has become much less challenging and provides the opportunity to explore reduced tillage sugar beet production. With the increasing threat of glyphosate resistant weeds however, it is necessary to consider using other herbicides with glyphosate to reduce the selection pressure for resistant weeds. A study was conducted at the University of Idaho Kimberly Research and Extension Center to compare several soil-active herbicides applied in combination with glyphosate for weed control in sugar beet grown in conventional tillage (CT), strip tillage (ST) and direct-seed tillage (DS) tillage systems. Sugar beet was planted May 6, 2015. The study was arranged as a 3 by 7 factorial split plot design. Tillage treatments were the main plots and seven herbicide treatments were the sub-plots. Sub-plots were 4 rows by 9.1 m with 56 cm row spacing. Each treatment was replicated four times. The entire study was sprayed with a preemergence glyphosate application at 1.12 kg ai ha^{-1} on April 20 to control emerged weeds primarily in the ST and DS treatments and again at the same rate at the 2-leaf sugar beet growth stage. The soil-active herbicides were applied with glyphosate (1.12 kg ha^{-1}) at the 6-leaf sugar beet growth stage. Soil-active herbicides included acetochlor, dimethenamid-P, ethofumesate, EPTC, and *s*-metolachlor at 1.26, 0.94, 1.12, 3.36, and 1.34 kg ha^{-1}, respectively. These herbicides were incorporated into the soil 1.5 hours after application using overhead sprinkler irrigation. Broadleaf and grass weeds ranged from 1.25 to 5 cm tall at this application. The primary weed species in this study were common lambsquarters, redroot pigweed, hairy nightshade, and green foxtail. Weed densities between the rows and within the rows were counted 14 and 30 days after the last application (DALA). Sugar beet yield was determined by harvesting the middle two rows of each plot on October 7 with a plot harvester. Sugar beet sucrose content, nitrate content, and conductivity were determined by collecting two 11 kg samples of roots for analysis. There were significant differences in weed populations between and within the rows for all weed species among the weed control treatments. However, the difference was

consistently between the untreated control and the herbicide treatments. There was a significant tillage by herbicide treatment interaction for redroot pigweed stand counts within the rows at 14 DALA and between the rows at 30 DALA. However, the differences were between tillage treatments in the untreated control only and did not include any herbicide treatments. Generally, there were more redroot pigweed in the CT treatment than the ST or DS treatments. There were no differences in redroot pigweed populations among the herbicide treatments that included a soil-active herbicide. There were no differences in sugar beet root or sucrose yield, sugar content, nitrate concentration, or conductivity among the tillage treatments. There were differences in sugar beet root yield, sucrose yield, and sugar content among the weed control treatments. Sugar content ranged from 17.02% to 18.07% with the untreated control averaging the lowest sugar content. Glyphosate + *s*-metolachlor had the highest sugar content and was significantly higher than the control, dimethenamid-P, and acetochlor. Typically, herbicide treatments do not affect sugar content. Differences in sugar beet root yield and sucrose yield were between the control and the rest of the herbicide treatments. The untreated control root and sucrose yield averaged 30 Mg/ha and 4,732 kg/ha, respectively. There were no differences in root or sucrose yield among the herbicide treatments, which averaged 105 Mg/ha and 16,929 kg/ha, respectively. There were no differences in sugar beet root nitrate concentration or conductivity among any of the treatments.

Evaluation of 2,4-D and Related Herbicides for Pre-emergent Control of *Brassica* Volunteers. Gabriel D. Flick*, Carol Mallory-Smith; Oregon State University, Corvallis, OR (080)

In the Willamette Valley of Oregon, post-harvest volunteer control in *Brassica* seed fields is important because of the increased number of hectares, long seed bank persistence, and the fungal pathogen *Leptosphaeria maculans*. Several trials investigating the utility of 2,4-D as a pre and post-emergent herbicide have been conducted. In the first experiment, canola (*Brassica napus*) seed was spread on the surface of potting soil then sprayed with 2,4-D amine at a rate of 2.24 kg ae/ha. Trays were sprayed 0, 7, and 14 days before watering. Twenty-eight days after watering all treatments were different from the controls, incorporation was not different, but there were differences among timings. Emergence was reduced by 84, 50, and 64% for the 0, 7, and 14 day treatments, respectively. The second experiment consisted of five herbicide treatments (2,4-D, MCPA, dicamba, dicamba plus diflufenzopyr, and pyrasulfotole plus bromoxynil) and a control. Mean total emergence of each treatment was different from the control. Visually, MCPA provided the greatest level of control. A third experiment investigated root and stem development of germinating seeds 1, 7, and 14 days after treatment with the same five herbicides used in experiment two. Stem and root lengths were different from controls for 2,4-D, MCPA, and dicamba. Measurements from timing one were different from the other treatment timings. These findings indicate that 2,4-D and MCPA may have utility to prevent the establishment of volunteer *Brassica* plants when applied after harvest.

Liquid Nicosulfuron Oil Dispersion Herbicide: a New Grass Control Option for Nicosulfuron-Tolerant Grain Sorghum. Jeffrey T. Krumm*[1], Kenneth L. Carlson[2], David W.

Saunders[2], Eric P. Castner[3], Robert N. Rupp[4], Bruce V. Steward[5], Keith D. Johnson[6]; [1]DuPont Crop Protection, Hastings, NE, [2]DuPont Crop Protection, Des Moines, IA, [3]DuPont Crop Protection, Weatherford, TX, [4]DuPont Crop Protection, Edmond, OK, [5]DuPont Crop Protection, Overland Park, KS, [6]DuPont Crop Protection, Grand Forks, ND (081)

Abstract not available

Competitiveness of Alternative Grain Crops with Weeds in Organic Wheat Production Systems. Nicole Tautges*[1], Ian C. Burke[1], Kristy Borrelli[2], E. Patrick Fuerst[1]; [1]Washington State University, Pullman, WA, [2]University of Idaho, Moscow, ID (082)

While demand for organic grain continues to grow, few growers in the dryland wheat production region of eastern Washington produce organic grain. Growers have cited weed control constraints as one of the main barriers to adopting organic small grain production. In organic systems, the inherent competitive ability of crops is a critical component of weed management. The objective of this study was to identify grain crop species that could compete with weeds in an organic small grains-based rotation. To assess the competitive ability of two alternative rotational grain crops, winter triticale and spring barley, relative total weed biomass and relative species-specific biomass of five weed species of particular management importance were examined over four years within the grain phase of a long-term organic reduced-tillage cropping systems experiment. Total relative weed biomass was lower in spring barley than in spring wheat, and was lower in winter triticale than in winter wheat. Winter triticale was more competitive with Canada thistle and downy brome, but less competitive with field bindweed, than winter wheat. Field bindweed, jointed goatgrass, and wild oat relative biomass was lower in spring barley than in spring wheat, a crop in which they are troublesome weeds in organic systems. Results suggest that winter triticale or spring barley, when grown with adequate soil nitrogen, could be incorporated into wheat rotations or substituted for wheat to increase crop competitiveness with winter annual grass and perennial broadleaf weed species that commonly reduce organic grain yields.

Management of Grass Weed Species with Soil-Applied Herbicides in Established Grasses Grown for Seed. Andrew G. Hulting*, Daniel W. Curtis, Kyle Roerig, Carol Mallory-Smith; Oregon State University, Corvallis, OR (083)

Annual bluegrass (*Poa annua*) and roughstalk bluegrass (*Poa trivialis*), among other grass weed species, invade newly established and established cool season grasses grown for seed in OR causing significant production and economic challenges for grass seed growers. Field experiments were conducted from 2007-2014 to determine the potential for using fall-applied applications of indaziflam, pyroxasulfone and a commercial premix of pyroxasulfone and flumioxazin to control grass weed species and volunteer crop plants in perennial ryegrass and tall fescue grown for seed. A range of application rates and timings of these products were compared to current industry standards including applications of diuron, metolachlor, dimethenamid and flufenacet plus metribuzin. Weed control efficacy, crop injury and crop yield were evaluated each year. Indaziflam applications at rates ranging from 14-44 g ai/ha resulted in excellent annual

bluegrass control (greater than 90%), but injured the perennial ryegrass and tall fescue at the higher application rates. However, the tall fescue was more tolerant to indaziflam than the perennial ryegrass. Applications rates of 14-28 g ai/ha of indazaiflam once during the life of the grass seed stand may be appropriate to manage annual bluegrass. Indaziflam applications over multiple years may reduce the life of the stand, particularly perennial ryegrass stands. Pyroxasulfone applications also resulted in excellent annual bluegrass control (greater than 90 %) and were less injurious to both tall fescue and perennial ryegrass than indaziflam applications. Application rates ranging from 50-100 g ai/ha resulted in little crop injury and no yield loss. Applications of the pyroxasulfone and flumioxazin premix at rates of 80-160 g ai/ha provided excellent annual bluegrass control. These studies suggest that these active ingredients provide good weed control as well as adequate crop safety when applied to established perennial ryegrass and tall fescue and are reasonable alternatives to current soil-applied herbicides used in grass seed production systems. Additional trials are ongoing to build needed efficacy and crop safety data sets with these herbicides should industry choose to pursue uses of these materials in grasses grown for seed.

Potential use Patterns for Pyroxasulfone + Flumioxazin for Grasses Grown for Seed. Daniel W. Curtis*, Kyle Roerig, Andrew G. Hulting, Carol Mallory-Smith; Oregon State University, Corvallis, OR (084)

Weed seed contamination is the greatest problem confronting grass seed producers. Extensive use of diuron has resulted in diuron resistant *Poa annua. Poa trivialis* has also become a major problem that producers have been unable to manage with diuron. Pyroxasulfone/flumioxazin has been identified as a potential replacement for diuron in cool season grass seed production in Western Oregon. Studies in 2008 in established perennial ryegrass indicated that pyroxasulfone could be used during the dormant season for preemergent control of grass weeds. In 2009, preemergence applications in established perennial ryegrass and in a carbon seeding study in perennial ryegrass demonstrated that this compound would be a good weed management tool. Marketing strategies have determined that the premix of pyroxasulfone/flumioxazin is the product that would be sold in grass seed production. In 2010-2011 studies, there was good crop tolerance with fall applications in established perennial ryegrass and spring planted tall fescue with this premix. In the established perennial ryegrass study, diuron resistant *Poa annua* control was 90% with application rates above 0.14 lb ai/A and 90% or greater with rates of 0.10 lb/A in the tall fescue. In 2012-2013, a study was conducted on spring planted tall fescue with a fall application of pyroxasulfone/flumioxazin at 0.14 lb/A. There were no difference in yields between an untreated control and the pyroxasulfone/flumioxazin treatment. The same season a study was conducted on carbon seeded perennial ryegrass with two pyroxasulfone/flumioxazin treatments, 0.10 and 0.14 lb/A. In this study which included populations of *Poa trivialis* and diuron resistant *Poa annua,* crop injury was initially 5% at 0.10 lb/A and 14% at 0.14 lb/A. Injury was less than 2 % in June and *Poa* spp. control was 100 %. Yield was 1192, 1272, and 814 lb/A, for the 0.10, 0.14 and the control respectively. In a study in established tall fescue on a commercial farm in 2012-2013 pyroxasulfone/flumioxazin was applied at 0.10 lb ai/A. There were no differences in yields compared with the untreated control. In 2014-2015 pyroxasulfone/flumioxazin was tested on a carbon seeding of tall fescue in early September. The tall fescue was irrigated through emergence.

Pyroxasulfone/flumioxazin rates were 0.10 and 0.14 lb/A. Crop injury persisted into the spring with the 0.14 lb/A treatment. Much of the injury was stand loss and stunting in areas where the irrigation caused standing water. This injury did not affect yield and the 0.14 lb/A treatment had the highest yield in the study. The injury observed in the 0.10 lb/A treatment diminished during the season and yields were greater than the untreated control. In grass seed crops pyroxasulfone/flumioxazin could be used as a preemergence substitute for diuron at rates of 0.10 lb ai/A or less with carbon seeding in the fall for stand establishment. In spring seeded grass seed crops, a preemergence application with pyroxasulfone/flumioxazin at rates of 0.10 – 0.14 lb/A depending on stand vigor, could be made to prevent fall germination of*Poa* spp. In established grass pyroxasulfone/flumioxazin could be used during dormancy either prior to fall rainfall or in early winter for preemergence control following an earlier preemergence application of another herbicide. Work is currently being conducted with indaziflam at these same application timings which would give growers the ability to rotate modes of action on these perennial grass seed plantings.

Crop Safety Assessment of Mutagenesis-derived ACCase Resistant Wheat Lines. Curtis M. Hildebrandt*, Philip Westra, Scott Haley, Todd Gaines; Colorado State University, Fort Collins, CO (085)

In wheat cropping systems, competition with winter annual grass species such as jointed goatgrass (*Aegilops cylindrica)*, downy brome (*Bromus tectorum)*, and feral rye (*Secale cereale)* can be a major problem for managers. To combat this problem, new technologies and chemistries are needed in order to give managers multiple options for grass control. Through a forward genetics screen using an induced mutagenesis method, mutant lines of wheat resistant to the ACCase inhibitor quizalofop p-ethyl were previously characterized, and further crosses were performed to create breeding lines. During the 2014-2015 growing season, a field crop safety trial was performed to assess these lines for relative levels of resistance and performance under two application timings, applied with and without a safener. One quizalofop susceptible line, four two-gene (mutation on two genomes) breeding lines, and three one-gene parent lines were compared. A split-split plot design was used in which quizalofop p-ethyl was applied at 92.5 g ai ha^{-1} with 1% MSO corresponding to the highest likely label application rate. Applications were made at either tillering or jointing growth stages. The two-gene breeding line CO14A065 showed the highest crop safety, with no changes from untreated control for any application timing or safener combination on yield, height, visual injury, straw weight or spike morphology ($p<0.05$). The best performing one-gene parent line, AF28, showed reduced yield and height, as well as higher visual injury ratings without the presence of the safener, but was not different from the control when safener was applied, and did not display changes in straw weight or spike morphology ($p<0.05$). Application after jointing made these reductions more pronounced. The susceptible line showed 100% mortality in all treatments. These results indicate that 2-gene lines will provide sufficient crop safety for likely quizalofop-p-ethyl applications to control winter annual grass weeds.

Trends in Green Foxtail and Wild Oat Resistance and Implications for Control. Brian M. Jenks*; North Dakota State University, Minot, ND (086)

Abstract not available

Characterization of Multiple Herbicide-Resistant Italian Ryegrass (*Lolium perenne ssp. multiflorum*) Populations from Winter Wheat Fields in Oregon. Mingyang Liu, Blake D. Kerbs*, Andrew G. Hulting, Carol Mallory-Smith; [2]Oregon State University, Corvallis, OR (087)

Multiple herbicide resistant Italian ryegrass populations have been confirmed in Oregon. Resistance patterns need to be characterized to identify alternative herbicides to effectively manage these populations. Two suspected resistant Italian ryegrass populations (R2 and R4) survived flufenacet plus metribuzin applications under typical western Oregon winter wheat production conditions. Following herbicide screening assays, populations R2 and R4 were found to be resistant to clethodim, pinoxaden, quizalofop, mesosulfuron-methyl, and flufenacet, but not acetochlor, dimethenamid-p, metolachlor, pyroxasulfone, imazapyr, sulfometuron or glyphosate. Only population R4 was resistant to diuron. Dose response curves were constructed to estimate rates of flufenacet and pyroxasulfone needed to reduce growth by 50% (GR_{50}) in R2, R4, and a known susceptible population (S). Estimated flufenacet doses needed to achieve GR_{50} were 438 g ai ha^{1-}, 308 g ai ha^{-1}, and 52 g ai ha^{-1} for R2, R4, and S respectively. Polymerase chain reactions (PCRs) were performed to amplify target site genes of acetolactate synthase (ALS), acetyl-CoA carboxylase (ACCase) and *psb*A for sequencing. A Ser-246-Gly substitution in the *psb*A gene and an Ile-2041-Asn substitution in the ACCase gene were found in population R4. Both R2 and R4 had an Asp-2078-Gly substitution in the ACCase gene. These mutations have previously been reported to provide resistance to ACCase and photosynthetic inhibiting herbicides. Addition of a cytochrome P450 inhibiting insecticide (chlorpyriphos) increased injury to both resistant populations from mesosulfuron-methyl, which indirectly indicates ALS resistance may be metabolic. Several herbicides were identified which could be used to manage these two populations.

Efficacy and Crop Tolerance of a New Pyroxsulam WG Formulation for Winter and Spring Wheat. Joseph Yenish*[1], Patricia Prasifka[2], Michael Moechnig[3], Roger Gast[4]; [1]Dow AgroSciences, Billings, MT,[2]Dow AgroSciences, West Fargo, ND, [3]Dow AgroSciences, Toronto, SD, [4]Dow AgroSciences, Indianapolis, IN (088)

TeamMate™ herbicide is a new pyroxsulam-based herbicide from Dow AgroSciences recently registered for use in winter and spring wheat (including durum), along with triticale and will provide flexible tank mix options to allow customization for broad-spectrum grass and broadleaf weed control. It is available in a water dispersible granular (WDG) formulation and contains a single active ingredient, pyroxsulam, at a concentration of 21.5 % on a w/w basis. TeamMate is labeled for applications to wheat or triticale at a single rate of 70 g/ha (1 oz/a), which delivers 15 g pyroxsulam/ha. It can be applied from the 3-leaf to jointing stage of crop growth for control of 13 species of grass weeds and 29 species of broadleaf weeds along with suppression of 7 and 4 species of grass and broadleaf weeds, respectively. Key grass weeds controlled include wild oat, yellow foxtail, Italian ryegrass, Persian darnel, and barnyardgrass, along with suppression of downy brome and green foxtail. Key broadleaf weeds controlled include bedstraw, redroot pigweed, common lambsquarter (<2 inches), volunteer canola, and several other mustard species with suppression of wild buckwheat. In field research conducted during 2014 and 2015 across WA, ID, MT, ND, SD, and MN, TeamMate demonstrated excellent crop safety with less than 5% injury observed 2 weeks after treatment and no effect on wheat yield. Moreover, TeamMate efficacy was similar to GoldSky™ herbicide on wild oats, Italian ryegrass, Persian darnel, yellow foxtail, and green foxtail in those same trials. When applied alone with NIS and AMS, TeamMate provided greater than 85% control of both wild buckwheat and common lambsquarters. Tank mixing 386 g 2,4-D LVE ae/ha with TeamMate increased common lambsquarters control to greater than 90%. TeamMate will provide growers effective grass and broadleaf control with the flexibility to tank mix other broadleaf herbicides for broad-spectrum control of all weeds encountered in U.S. cereals. ™®Trademark of The Dow Chemical Company ("DOW") or an affiliated company of Dow.

Pyroxasulfone Postemergence Grass Control. Codee Z. Lee*[1], Kirk A. Howatt[2]; [1]North Dakota State University, Fargo, ND, [2]NDSU, Fargo, ND (089)

Pyroxasulfone is a very long chain fatty acid inhibitor labeled to control grasses and small-seeded broadleaf weeds. Little information is available regarding the use of this product as a postemergence herbicide. The objectives of this study were to determine efficacy of pyroxasulfone postemergence to control grass and broadleaf weeds and to determine enhancement of pyroxasulfone when applied postemergence with different adjuvants. Application timing and adjuvant field experiments were conducted in 2015 near Prosper and Fargo, North Dakota. Each study was established as a randomized complete block design (RCBD) with four replicates. Adjuvant study treatments included pyroxasulfone mixed with various adjuvant classes. Adjuvants did not improve pyroxasulfone control of weeds postemergence compared with pyroxasulfone alone. Timing trial applications of pyroxasulfone included 63, 119, 182, and 238 g ha^{-1} at spike, one-leaf, and two-leaf wheat growth stages. Pyroxasulfone applied postemergence gave little to no control of broadleaf weeds. Foxtail spp. growth decreased as pyroxasulfone rates increased. Also, pyroxasulfone decreased foxtail survival with earlier application timing. Foxtail control provided by pyroxasulfone led to further focus on grasses in the greenhouse. Green foxtail, downy brome, and Japanese brome were controlled greater than 90% with pyroxasulfone applied postemergence, while foxtail barley and Persian darnel were controlled between 80 and 90%. Future studies will include greenhouse experiments to evaluate pyroxasulfone’s effects when applied to the soil vs effects applied to foliage, and field experiments with pyroxasulfone in tankmix to evaluate supplemental control of troublesome weeds such as downy brome.

Mesosulfuron plus Thiencarbazone for Weed Control in Winter Wheat. Monte D. Anderson*; Bayer CropScience, Spangle, WA (090)

Mesosulfuron plus thiencarbazone is a premix herbicide being developed by Bayer CropScience to enhance the weed spectrum of grass and broadleaf weed control over mesosulfuron alone in winter wheat. The most significant features will be the improved consistency on grassy weeds such as downy brome and providing a significant level of efficacy on rattail fescue. Current selective herbicides in cereals lack effective postemergence activity on rattail fescue. The increase in no till or direct seeding cropping systems the past ten to fifteen years in the Pacific Northwest have allowed rattail fescue to dramatically increase in scope and intensity. The addition of thiencarbazone improves the efficacy of mesosulfuron by at least 40% on rattail fescue in studies conducted in 2014 and 2015. Overall grass and broadleaf efficacy improved at least 10% when comparing mesosulfuron to mesosulfuron plus thiencarbazone in studies conducted the past three years. Refinement of the safener ratio has been evaluated in these studies and a higher level of the safener mefenpyr diethyl will be offered in this combination. The rotational characteristics of this herbicide combination have shown no appreciable differences to date when planting back to the key rotational crops in the non-irrigated areas of the Pacific Northwest. Mesosulfuron plus thiencarbazone should offer the same wide window of application and rotational flexibility as mesosulfuron while improving the consistency of grass control, along with providing a new tool for the control of rattail fescue in winter wheat.

Biology and Management of Volunteer Buckwheat in Wheat. Vipan Kumar*, Prashant Jha, Shane Leland, Anjani J, Charlemagne A. Lim; Montana State University, Huntley, MT (108)

Common or tame buckwheat (*Fagopyrum esculentum* L.) is a summer annual, broadleaf herb that is mainly grown as a food grain for human consumption, feed for livestock, and as a green manure or cover crop in the Northern Great Plains (NGP), including Montana. Occurrence of volunteer buckwheat in the succeeding wheat crop is an increasing management concern for growers in the region. Field experiments were conducted at the Montana State University Southern Agricultural Research Center near Huntley, MT to (1) evaluate the effectiveness of postemergence (POST) herbicide programs on control and fecundity of volunteer buckwheat in wheat, and (2) determine the ultimate impact on wheat yield and grain quality. Spring wheat variety "Vida" was planted with a seeding rate of 67 kg ha^{-1} on May 1, 2015. Prior to wheat planting, seeds of common buckwheat variety "Mancan" were uniformly broadcasted and mixed in the soil by harrowing to simulate buckwheat volunteers. A randomized complete block design with three replications was used. Herbicides were applied using a CO_2-operated handheld boom sprayer calibrated to deliver 94 L ha^{-1} at 276 kPa. All treatments were applied at the 8- to 10-leaf (lf) stage of wheat, when buckwheat volunteers had reached 3- to 4 lf stage. Among the tested POST herbicide programs, bromoxynil + MCPA (560 + 560 g ha^{-1}), bromoxynil + fluroxypyr (285 + 71 g ha^{-1}) and florasulam + fluroxypyr + pyroxsulam (2.5 + 99 + 15.4 g ha^{-1}) effectively controlled (≥ 95%) buckwheat volunteers at 21 d after treatment (DAT). Volunteer buckwheat control with bromoxynil + pyrasulfotole (240 + 30 g ha^{-1}) and thifensulfuron + tribenuron + 2,4-D (17 + 8 + 280 g ha^{-1}) averaged 88% at 21 DAT. Control with dicamba (140 g ha^{-1}), fluroxypyr (156 g ha^{-1}), and clopyralid (666 g ha^{-1}) did not exceed 80% at 21 DAT. Consistent with percent control, bromoxynil + MCPA, bromoxynil + fluroxypyr, and florasulam + fluroxypyr + pyroxsulam prevented seed production from buckwheat volunteers. The survived volunteer buckwheat plants treated with dicamba and clopyralid produced an average of 48 seeds m^{-2} at maturity. An infestation of volunteer buckwheat at a density of 15 to 20 plants m^{-2} reduced the wheat grain yield by 58% in nontreated plots. Wheat yield averaged 4,132 kg ha^{-1} with bromoxynil + fluroxypyr, and was not different from bromoxynil + pyrasulfotole, bromoxynil + MCPA, thifensulfuron + tribenuron + 2, 4-D, and florasulam + fluroxypyr + pyroxsulam treatments. Based on these results, growers should utilize effective POST herbicides including bromoxynil + MCPA, bromoxynil + fluroxypyr, or florasulam + fluroxypyr + pyroxsulam for effective management of volunteer buckwheat in the succeeding wheat crop. Due to the strict restrictions on buckwheat seed contamination in US wheat exports, control efforts should aim on 'zero seed tolerance' approach for preventing seed bank replenishment of the buckwheat volunteers in wheat.

Halauxifen-methyl plus Florasulam for Pre-seed Weed Control in Spring Cereals. Patricia Prasifka*[1], Michael Moechnig[2], Joseph Yenish[3], Roger Gast[4]; [1]Dow AgroSciences, West Fargo, ND, [2]Dow AgroSciences, Toronto, SD, [3]Dow AgroSciences, Billings, MT, [4]Dow AgroSciences, Indianapolis, IN (109)

Arylex™ active (halauxifen-methyl) a new active ingredient from Dow AgroSciences, is a novel synthetic auxin (WSSA group 4) herbicide from the new arylpicolinate chemical class being developed for the U.S. and several other major cereal markets around the globe. The first Arylex U.S. product, Quelex™ herbicide is a premix with florasulam, formulated as a water dispersible granule (WDG). It will be registered in wheat (including durum), barley and triticale for pre-plant, pre-emergence, or post-emergence applications with a proposed use rate of 52.5 grams of product/ha (0.75 oz pr/acre) [Arylex (halauxifen-methyl 5.25 g ae/ha) + florasulam (5.25 g ai/ha)]. It offers a unique broadleaf weed control spectrum and favorable crop rotation flexibility for cereals producers. Field research was conducted during 2014 and 2015 at 12 locations across northwest ND and northeast MT to determine the efficacy and crop safety of Quelex applied in conjunction with glyphosate as a pre-seed burndown ahead of spring cereals. Weed control efficacy and crop response of Quelex + glyphosate was compared to glyphosate plus commercial formulations and pre-seed rates of saflufenacil, dicamba or carfentrazone. In most cases Quelex + glyphosate demonstrated superior control of weeds such as volunteer canola (*Brassica rapa*), narrow-leaf hawksbeard (*Crepis tectorum*), and wild buckwheat (*Polygonum convolvulus*) compared with glyphosate alone, and similar or greater control compared to the other commercial tank-mixtures. Quelex + glyphosate also demonstrated good crop safety on spring wheat (including durum) and barley. Quelex herbicide with Arylex Active will provide cereal growers with an effective herbicide option for many difficult to control broadleaf weeds traditionally targeted by glyphosate in a burndown application. ™®Trademark of The Dow Chemical Company ("DOW") or an affiliated company of Dow.

Bicyclopyrone + Bromoxynil: A New Postemergence Herbicide for Broadleaf Weed Control in Cereals. Peter C. Forster*[1], Donald J. Porter[2], Monika Saini[2]; [1]Syngenta Crop Protection, Eaton, CO, [2]Syngenta Crop Protection, Greensboro, NC (110)

Syngenta is developing a new selective postemergence herbicide premix for the US market containing Bicylopyrone + Bromoxynil that will provide broad spectrum broadleaf weed control in wheat and barley. The brand name for this new premix is Talinor™ herbicide. This premix contains two active ingredients with different modes of action, bicyclopyrone, a HPPD inhibitor (Site of Action Group 27), and Bromoxynil, a PS II inhibitor (Site of Action Group 6). Talinor at 213 - 283 g/ha plus CoAct+™ adjuvant at 64-84 g/ha will provide excellent control of some of the more troublesome broadleaf weeds in cereals, such as Russian thistle, kochia, wild buckwheat, prickly lettuce and mayweed chamomile, including populations that may be resistant to ALS-inhibitor and auxin herbicides. Talinor provides excellent crop safety and, upon registration, may be applied to all varieties of spring wheat (including durum), winter wheat and barley. Talinor can be tank mixed with graminicides such as Axial® XL for one-pass grass and broadleaf weed control. Talinor will be launched in the US market in 2017 pending EPA approval.

A New Herbicide for Control of Kochia and other Broadleaf Weeds in Fallow and Wheat. Raymond L. Pigati*[1], Greg K. Dahl[2], David A. VanDam[1], Ryan J. Edwards[3], Eric P. Spandl[1]; [1]WinField Solutions, Shoreview, MN, [2]WinField Solutions, River Falls, WI, [3]Winfield Solutions, River falls, WI (111)

Kochia (*Kochia scoparia* L.) is a summer annual broadleaf weed of cereal crops and fallow areas in the western and central United States and is considered a noxious weed or invasive species in many counties and states. Over the past 9 years, multiple Kochia populations from 9 different states have been documented with resistance to glyphosate. These resistant populations have decreased the effectiveness of glyphosate applications. To help improve Kochia control in cereal crops and fallow areas, a novel ratio of herbicides was developed. Field trials were conducted in 2015 at multiple field sites across the United States with this new combination of 2,4-D ester, bromoxynil and fluroxypyr to effectively control Kochia and other broadleaf weeds. Results showed Kochia control was greater than 95% in all field trials. Similar trends in control were also observed in all other broadleaf weeds tested. This novel herbicide will provide another option to use for the control of glyphosate resistant Kochia in cereal crop and fallow areas.

Effect of Winter Wheat Stubble Height on Dry Bean Growth and Development. Clint W. Beiermann*, Andrew R. Kniss, David A. Claypool; University of Wyoming, Laramie, WY (112)

Direct harvesting of dry edible bean increases time and energy efficiency compared to conventional harvest, but can result in greater harvest loss. The perceived increase in harvest loss has limited adoption of direct harvest by many producers in Wyoming. We hypothesized that shade effects from previous crop stubble could reduce direct harvest loss by causing dry bean to grow taller or produce pods higher above the soil surface. A large-scale field study was conducted in 2015 to test this hypothesis under field conditions. Wheat stubble was cut at 19, 25, and 36 cm heights the previous year and dry bean was planted on May 29th directly into these treatments with no tillage. An area of the field was tilled before planting and served as a comparison to the stubble treatments. Soil temperature was reduced as stubble height increased ($P<0.001$) when measured

12 days after planting. Final dry bean stand was highest in the tilled area and decreased as stubble height increased ($P<0.001$). Dry bean cotyledon and unifoliate heights were lowest on the tillage treatment and increased with stubble height ($P<0.001$). Total dry bean yield (harvested + harvest loss) was not significantly different among wheat stubble treatments. There was a significant reduction in harvest loss where dry bean was planted into wheat stubble ($P<0.001$), due to bean pods being held higher above the soil surface ($P<0.001$).

Venice Mallow (*Hibiscus trionum*) Control in Dry Beans. Gustavo M. Sbatella*; University of Wyoming, Powell, WY (113)

Environmental conditions in northwestern Wyoming are optimal for dry bean seed production. Weeds affect seed quality, therefore farmers try to reach harvest with clean fields in order to be certified. Late emerging weeds, such as Venice mallow (VM) interfere with harvest and affect quality. A field study was conducted near Burlington, WY, to evaluate tank mixing lay-by treatments with post emergence applications to improve VM control late in the season. Pinto beans ('Othello') were planted under furrow irrigation, on June 1. EPTC (3 pt. /a) + dimethenamid-p (14 oz. /a) and EPTC (3 pt. /a) + ethalfluralin (2 pt. /a) were applied pre-plant incorporated (PPI) and followed by post emergence applications of imazamox (4 oz. /a) + bentazon (1.5 pt. /a) tank mixed with dimethenamid-p (7 and 14 oz. /a), and halosulfuron (0.66 oz. /a). Weed counts were recorded before post application, 15 days after treatment (DAT) and before harvest to determine treatment efficacy. Plots were evaluated for seed certification, and harvested on September 1. The number of VM plants didn't differ between PPI treatments previous to POST applications. VM plant density was reduced 15 DAT by all post emergence treatments and levels of control remained similar until harvest. Dry beans yields were higher in treated plots, when compared to the non-treated check. No significant visible crop injury was observed after herbicide applications. All treatments had 100% of the plots certified approved at harvest with the exception of EPTC (3 pt. /a) + dimethenamid-p (14 oz. /a) + imazamox (4 oz. /a) + bentazon (1.5 pt. /a) + halosulfuron (0.66 oz. /a), with 63% of the plots approved.

Effect of Row Spacing, Plant Architecture, and Herbicides on Weed Control in Dry Bean (*Phaseolus vulgaris*). Michael L. Thornton*[1], Don W. Morishita[2]; [1]University of Idaho, Kimberly, ID, [2]University of Idaho, Twin Falls, ID (114)

Weed control is one of the most difficult and critical pest management issues in dry bean production. In order to maintain optimum yields, a good weed management plan is necessary. A field study was conducted in 2014 and 2015 to determine the effect of row spacing, plant architecture, and herbicide treatments on season long weed control in dry bean under sprinkler irrigation. A total of 24 treatments were established in a 2 by 2 by 6 factorial randomized complete block design. Two row spacings, narrow row (19 cm) and wide row (56 cm), were compared along with two pinto bean varieties 'Sequoia' (type 2 growth habit) and 'Othello' (type 3 growth habit), and six weed control treatments. The weed control treatments included a preemergence (PRE) only treatment, three different PRE followed by postemergence (POST) applications, an untreated control and handweeded control. Weed counts, crop injury and weed control evaluations were taken approximately 7, 14, and 28 days after last application. Cultivation was included only in the wide row spacing treatments. Narrow rows yielded higher than wide rows in both varieties. However, more weeds were found in narrow rows versus wide rows likely due to cultivation. These results are consistent with other research on row spacing effects. Weed control was greater in all treatments that had sequential applications (PRE fb POST). All treatments yielded higher than the untreated control. Treatments that consisted of only a PRE application yielded significantly lower than those that had sequential herbicide applications.

Can EPTC increase POST Heribicide Efficacy? Jason W. Adams*[1], Rich Zollinger[2]; [1]North Dakota State University, FARGO, ND, [2]North Dakota State University, Fargo, ND (115)

EPTC is a soil-applied herbicide registered for use in many specialty crops and provides limited weed control applied alone. However, the lipid synthesis inhibitor mode of action of EPTC may improve POST applied herbicide efficacy by reducing cuticle production. Studies were performed in 2014 and 2015 to assess whether EPTC applied PRE increased POST-applied herbicide efficacy. Treatments were arranged as a randomized complete block design with three replications. EPTC or ethofumesate were applied PRE in late May 2014 at labeled field rates followed by bentazon at 1120 g ha^{-1}, halosulfuron at 35 g ha^{-1}, or fomesafen at 210 g ha^{-1} applied POST to 2 to 3 inch weeds in late June. EPTC was applied in late May 2015 at 980, 1960, and 2940 g ha^{-1} followed by bentazon, halosulfuron, or fomesafen as previously described. Visible injury to redroot pigweed (*Amaranthus retroflexus* L.), lambsquarters (*Chenopodium album* L.), and common ragweed (Ambrosia artemisiifolia L.) was evaluated 14 and 28 DAT. EPTC applied PRE at labeled field rates increased the efficacy of all POST herbicides to greater than 90% control 14 and 28 DAT on all weeds. The benefit of EPTC was more apparent at 28 DAT when control remained higher compared to POST herbicides alone. The rate of EPTC should be greater than or equal to 1960 g ha^{-1} in order to achieve an acceptable level of weed control.

Herbicide Tolerance of Direct-Seeded Guayule (*Parthenium argentatum*). William McCloskey*[1], Guangyao Wang[2]; [1]University of Arizona, Tucson, AZ, [2]Bridgestone Americas Agro Operations, Eloy, AZ (131)

Guayule, *Parthenium argentatum* (Gray), is a xerophytic shrub native to the Chihuahuan desert that produces natural latex. Guayule rubber and Hevea rubber have the similar physical and structural properties and can be used to make the same products (e.g., tires and latex gloves). Guayule production in the 2000s started with transplanting 5 to 8 leaf guayule seedlings into fields. Early season weed control was a significant challenge often requiring expensive hand weeding in addition to tillage. The tolerance of guayule to various herbicides was assessed by topically spraying after the transplants were established; plants were typically about 8 inches tall with 20 or more mature leaves when treated. Several section 24c herbicides labels were obtained based on research conducted in 2006 to 2008 including pendimethalin (Prowl H_2O), carfentrazone-ethyl (Aim EC), pyraflufen ethyl (ET) and fluazifop-P-butyl (Fusilade DX). Established guayule at this growth stage also appeared to be tolerant to flumioxazin (Chateau) and oxyfluorfen (GoalTender). Recently methods for direct-seeding guayule fields have been developed. Early season weed control will be an even greater challenge than in transplanted guayule fields and may involve spraying herbicides on much younger and smaller seeding. Thus, research was conducted to identify preemergence herbicides that could be used to control weeds in seedling guayule without injuring the crop. Guayule was planted on 9/29/14 on 40 inch wide beds using a direct-seeding method. In experiment 1, the plots were 2 rows wide by 10 feet long arranged in a randomized complete block design with 14 treatments that were replicated 4 times. The herbicides were applied at the guayule 2 to 4 leaf growth stage using a CO_2 pressurized backpack sprayer, 4 nozzle boom and Greenleaf Airmix 11002 flat fan nozzles calibrated to deliver 18.8 gallons per acre. The herbicides were applied broadcast over-the-top of guayule seedlings on November 4, 2014 and were incorporated into the soil by irrigation water from a center-pivot irrigation system. The herbicide tolerance of guayule was assessed by visually evaluating phytotoxicity and stunting caused by the herbicides on November 14 and December 10, 2014. A second similar study, Experiment 2, was conducted in the spring of 2015 using similar methods and treatments. Experiment 2 was direct-seeded on April 14, 2015 and was sprayed topically on May 19, 2015 using the boom described earlier except that the carrier volume was 19.1 gallons per acre. Phytotoxicity in the second experiment was evaluated on June 4, 2015 by visually estimating phytotoxicity and by comparing pre- and post-treatment stand counts.

Injury symptoms in Experiment 1 were apparent a few days after treatment with significant injury developing 10 days after treatment (DAT). At 36 DAT, oxyfluorfen (GoalTender) at 1.25 lb ai/A and 2 lb ai/A caused 65% and 70% phytotoxicity, respectively, compared to untreated plants. Flumioxazin at 0.096 and 0.191 lb ai/A also caused significant but less severe injury, 31% and 37% phytotoxicity, respectively. Pyraflufen-ethyl (ET), a PPO inhibitor with no preemergence activity also caused 32% phytotoxicity at 0.0048 lb ai/A. Pendimethalin (Prowl H_2O) at 0.95 and 1.9 lb ai/A, carfentrazone (Spartan) at 0.094 and 0.188 lb ai/A, dacthal at 6 and 9 lb ai/A and S-metolachlor at 0.63 and 1.27 lb ai/A were the preemergence herbicides in the study that caused either no injury or minor, non-significant injury to guayule in Experiment 1. Experiment 1 was characterized highly variable plant sizes and a lot variability between the two beds in each plot caused in part by non-uniform irrigation from the center-pivot system. Experiment 2 used the same treatment list as Experiment 1 except that the pyraflufen-ethyl treatment was deleted. In addition, the planting method in Experiment 2 allowed individual plants to be sprayed resulting in a better estimation of guayule seedling susceptibility to the herbicide treatments. At 16 DAT, oxyfluorfen at 1.25 lb ai/A and 2 lb ai/A caused 95% and 98% phytotoxicity, respectively, compared to untreated plants. Similarly, flumioxazin at 0.096 and 0.191 lb ai/A caused 86% and 96% phytotoxicity, respectively. Metolachlor at 0.63 and 1.27 lb ai/A caused less severe injury with 21% and 30% phytotoxicity, respectively. Pendimethalin at 0.95 and 1.9 lb ai/A, carfentrazone at 0.094 and 0.188 lb ai/A, and dacthal at 6 and 9 lb ai/A were the preemergence herbicides in Experiment 2 that caused minor, non-significant injury to guayule. Based on pre-spray and post-spray stand-counts, at 16 DAT, oxyfluorfen at 1.25 lb ai/A and 2 lb ai/A reduced stands 68% and 92%, respectively, compared to untreated plots. Similarly, flumioxazin at 0.096 and 0.191 lb ai/A reduced stands 77% and 90%, respectively. The other preemergence herbicides did not significantly reduce plot plant populations. These results indicate that as expected guayule seedlings (3 true leaves) are more sensitive to preemergence herbicides, especially oxfluorfen and flumioxazin, sprayed topically than guayule transplants. However, the guayule seedlings do appear to have enough tolerance to some of the tested herbicides to warrant continued research and development of data to support local special needs (24c) herbicides labels.

Linuron Weed Control Systems in Eastern WA Chickpea. Alan J. Raeder*[1], Louise Lorent[1], Gil Cook[2], Ian C. Burke[1]; [1]Washington State University, Pullman, WA, [2]TKI NovaSource, Spokane, WA (132)

Linuron was recently granted registration as Lorox for broadleaf weed control in chickpea (*Cicer arietunum* L.). Linuron as Lorox is considered expensive by growers. Therefore, studies were conducted in 2012, 2013, 2014 and 2015 to determine if effective control of mayweed chamomile and common lambsquarters could be achieved with reduced rates of linuron in mixture with other preemergence herbicides. Each year the study was arranged as a randomized complete block design with four replications and chickpea was planted in early to mid-May. Treatments consisted of linuron at 420, 560, or 700 plus saflufenacil at 25 or 37, flumioxazin at 54 or 72, metribuzin at 158, fomesafen at 53 or 105, or pyroxasulfone at 85 g ai ha^{-1}. Grasses were controlled by postemergence applications of clethodim. Control of common lambsquarter (CHEAL) and mayweed chamomile (ANTCO) was evaluated by visual estimation each year, while prickly lettuce (LACSE) was assessed in 2013 and 2014. Injury was observed in 2015 for linuron plus flumioxazin, but did not result in yield loss. Yields were similar among treatments in 2012 and 2013. In 2014, linuron plus saflufenacil (420 plus 25, 420 plus 37, and 560 plus 37) and linuron plus fomesafen (420 plus 105) resulted in greater yields compared to chickpea not treated with an herbicide. In 2015, all treatments resulted in greater yields compared to nontreated. In 2015, control of CHEAL was similar among all treatments, except linuron plus fomesafen (420 plus 53 or 105 and 560 plus 53). ANTCO control was 94% using linuron plus saflufenacil (420 and 560 plus 37) in 2014 and in 2015, control ranged from 76 to 92% for all treatments, except linuron plus metribuzin. Linuron at reduced rates plus saflufenacil or flumioxazin were effective treatments for ANTCO and CHEAL in eastern WA chickpea.

Performance of Certain Herbicides as Influenced by Novel Adjuvant Systems. Ryan J. Edwards*[1], Greg K. Dahl[2], JoAnna A. Gillilan[3], Joe V. Gednalske[2], Eric P. Spandl[4], Raymond L. Pigati[4], David A. VanDam[4]; [1]winfield solutions, River falls, WI, [2]WinField Solutions, River Falls, WI, [3]WinField Solutions, Springfield, TN, [4]WinField Solutions, Shoreview, MN (133)

The performance of certain herbicides is increased with the use of oil type adjuvants. However, oil adjuvants are not recommended for use with glyphosate. Methylated Seed Oil-High Surfactant Oil Concentrates (MSO-HSOC) are a newer generation of oil based adjuvants. MSO-HSOC (e.g. Destiny HC and Superb HC) are based on 25-50% w/w surfactant with a minimum of 50% w/w oil. MSO-HSOC have shown excellent compatibility with glyphosate while providing equivalent performance as other oils. A new MSO-HSOC (AG14039) provides optimal weed efficacy similar to other HSOC adjuvants and added drift control. Field trials were conducted across the United

States on multiple crop types and weeds to determine the effect of AG14039 on the performance of fomesafen, saflufenacil, clethodim, quinclorac + imazethapyr, topramazone and glyphosate. In all trials, AG14039 provided similar weed efficacy as compared to similar MSO-HSOC for velvetleaf, common lambsquarter, pigweeds, volunteer corn and other weeds.

Dicamba Droplet Retention on Common Lambsquarters (Chenopodium album) Leaves as Influenced by Nozzle Type, Application Pressure, and Adjuvant. Cody F. Creech*; University of Nebraska, Scottsbluff, NE (134)

Dicamba can cause significant injury to susceptible plants if moved off-target via particle drift. To minimize this risk, it is recommended that dicamba applications be made using application technologies that minimize small spray droplets. When spray droplets reach the leaf surface, droplets may shatter, bounce, roll off, or be retained on a leaf surface. This study was conducted to evaluate how nozzle types, adjuvants, and pressure impact spray retention on a leaf surface. Common lambsquarters plants were grown inside a greenhouse located at the Pesticide Application Technology Laboratory, West Central Research and Extension Center, University of Nebraska-Lincoln in North Platte, NE. Three nozzles (XR, AIXR, and TTI) were evaluated at 138, 259, and 379 kPa. Dicamba (0.14 kg ae ha^{-1}) was applied alone and with a non-ionic surfactant (NIS), crop oil (COC), methylated seed oil (MSO), silicone, or drift reduction adjuvant (DRA) and contained 1, 3, 6, 8-pyrene tetra sulfonic acid tetra sodium salt as a tracer. Dicamba spray retention when applied using the XR nozzle, which produced the smallest spray droplets, was 1.75 times greater than when applied with the TTI nozzle which had the largest spray droplets. Applying dicamba with MSO resulted in spray retention on leaf surfaces nearly four times the amount achieved when applying dicamba without an adjuvant. The lowest application pressure (138 kPa) had more than 10% more dicamba spray retention compared to the higher pressures 259 and 379 kPa. Thus, dicamba applications should be made using adjuvants, nozzles, and pressures that maximize spray retention on the leaf surface while also minimizing the drift potential of the application.

Efficacy of Glyphosate and Dicamba Tank-Mixes in Kochia. Junjun Ou*[1], Curtis R. Thompson[1], Philip W. Stahlman[2], Mithila Jugulam[1]; [1]Kansas State University, Manhattan, KS, [2]Kansas State University, Hays, KS (135)

Kochia (*Kochia scoparia*) is one of the most troublesome weeds of the Great Plains of North America. Glyphosate and dicamba have been used for decades to control kochia. However, as a result of extensive use of these herbicides, glyphosate and/or dicamba resistant kochia populations have evolved across the Great Plains. Tank-mixing of dicamba and glyphosate may offer a viable option for controlling dicamba and glyphosate resistant kochia, if these two herbicides act synergistically. To investigate this possibility, assessment of tank-mixes in greenhouse and field conditions (two locations), and physiological basis of herbicide interaction have been conducted. Using a known susceptible kochia population (S) under greenhouse conditions, 19 combinations (0-2.5X of dicamba, X=560 g ae/ha; 0-2.5Y of glyphosate, Y=840 g ae/ha) of tank-mixes were tested on a dicamba and glyphosate resistant (R) population. The results indicated that tank-mixes had good control of S kochia. However, 2.5Y glyphosate alone provided the best control of R kochia under both greenhouse and field conditions, but the efficacies of all other tank-mixes were lower than 2.5 Y glyphosate, including 2.5X dicamba + 2.5Y glyphosate. ^{14}C labelled dicamba or glyphosate (tank-mix) uptake and translocation experiments were conducted using 2.5X dicamba + 2.5Y glyphosate by comparing with treatments that had dicamba or glyphosate alone. The results suggest that tank-mixing of dicamba and glyphosate has substantial antagonism effects due to significantly reduced translocation of both dicamba and glyphosate in R kochia. In conclusion, tank-mixing of dicamba and glyphosate may not be a viable option for controlling dicamba and glyphosate resistant kochia, due to antagonistic effect resulting in significantly reduced translocation of these herbicides.

Heribicide Programs for Kochia Control in Dicamba-Tolerant Soybeans. Jeffrey T. Krumm*[1], David H. Johnson[2], Keith D. Johnson[3], Bruce V. Steward[4], Robert N. Rupp[5], Eric P. Castner[6]; [1]DuPont Crop Protection, Hastings, NE, [2]DuPont Crop Protection, Des Moines, IA, [3]DuPont Crop Protection, Grand Forks, ND, [4]DuPont Crop Protection, Overland Park, KS, [5]DuPont Crop Protection, Edmond, OK, [6]DuPont Crop Protection, Weatherford, TX (136)

Abstract not available

Introducing BOLTTM Technology: A New Herbicide System for Cleaner Fields and Greater Management Flexibility in Soybean. David H. Johnson*[1], Helen Flanagan[2], Jeff Carpenter[3], Stephen Strachan[4], Steven Mitchell[5], Andre Trepanier[5], Mark Vogt[5], Scott Sebastian[5]; [1]DuPont Crop Protection, Des Moines, IA, [2]DuPont Crop Protection, Greenwood, IN, [3]DuPont Crop Protection, Johnston, IA, [4]DuPont Crop Protection, Newark, DE, [5]DuPont Pioneer, Johnston, IA (137)

Abstract not available

Multiple Resistance in Palmer Amaranth in Kansas. Phillip W. Stahlman*, Jennifer Jester; Kansas State University, Hays, KS (151

Palmer amaranth (*Amaranthus palmeri*) is a major cropland weed in Kansas in all but the northeastern part of the state. Resistance to ALS- and PS II-inhibiting herbicides in separate Kansas Palmer amaranth populations was confirmed in 1993 and 1995, respectively, and the first case of multiple resistance (ALS-, HPPD-, and PS II-inhibitors) in the same population was first confirmed in 2009. Resistance to glyphosate in multiple populations from south-central and east-central Kansas was confirmed in 2011 and 2012, and appeared to spread widely during the next couple years. In fall 2014, seed was collected from 40 ± 5 Palmer amaranth plants in each of 157 fields in 24 south-central and northwestern Kansas counties and composited into one sample per field (accession) after drying and cleaning. All seed was placed in cold storage (-0 C) for approximately 3 months and then moved to storage at room temperature. In spring 2015, each accession was seeded into 10 by 10 cm plastic pots filled with commercial potting mix and grown in a greenhouse with 14-h photoperiod. Sunlight was supplemented with artificial illumination. When approximately 6- to 9-cm tall, plants were sprayed with a dose of 870 g ha^{-1} glyphosate and 1% w/v ammonium sulfate. Each pot contained a minimum of 10 plants. At 7 days after spraying, the number of living and dead plants were counted. All plants in 31% of the accessions died, whereas 69% of the accessions were either segregating or completely resistant to glyphosate. Results of additional greenhouse screening reported elsewhere indicated several accessions were resistant to multiple herbicide modes of action. Here we report the response of eight accessions to single doses of glyphosate (1260 g ae ha^{-1}) + 2% w/v ammonium sulfate, 2,4-D ester (870 g ae ha^{-1}), dicamba (280 g ae ha^{-1}), chlorsulfuron (26 g ha^{-1}) + 0.25% NIS, atrazine (1120 g ha^{-1}) + 1% v/v COC, mesotrione (105 g ha^{-1}) + 1% v/v COC and 2.5% v/v UAN, and saflufenacil (25 g ha^{-1}) + 1% MSO compared to untreated plants of each accession. Herbicides were applied to 12 plants of each accession when 10 to 12-cm tall. Experimental runs were repeated 6 days apart. Plant mortality and individual plant fresh and dry weights were determined at 14 DAT for plants that were clearly dead at that time and at 21 DAT for all remaining plants. Three of the eight accessions tested resistant to glyphosate, two of eight were severely injured but survived both dicamba and 2,4-D, all eight accessions were resistant to chlorsulfuron and atrazine, and five of eight survived mesotrione; however, all eight accessions were susceptible to saflufenacil. These results are consistent with earlier experiments indicating multiple Palmer amaranth accessions with resistance to as many as four herbicide modes of action.

Population Genomics of Glyphosate-Resistant Palmer Amaranth (*Amaranthus palmeri*) using Genotyping-by-Sequencing (GBS). Anita Kuepper*[1], Harish Manmathan[1], William McCloskey[2], Eric Patterson[1], Scott J. Nissen[1], Scott Haley[1], Todd Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]University of Arizona, Tucson, AZ (152)

Throughout the southeastern and southwestern United States, populations of Palmer amaranth (*Amaranthus palmeri*) have been identified with evolved resistance to the herbicide glyphosate. This project aims to determine the degree of genetic relatedness among a set of glyphosate-resistant and –susceptible lines by analyzing patterns of phylogeography and diversity on an intraspecific level. Seven different lines of Palmer amaranth from different geographic regions were tested against a glyphosate-resistant line from an Arizona locality for glyphosate resistance. The goal is to ascertain whether resistance evolved independently in the Arizona locality, or whether resistance spread from outside to the location. For example, the transportation of resistant seeds in harvesting equipment could be a source of gene flow via seed migration. The accumulation of shikimic acid via the shikimate assay and EPSPS copy number and were tested to confirm resistance. The susceptible lines showed an average of 41 mg/ml shikimic acid while the resistant lines showed an average of 0.1 mg/ml shikimic acid accumulation after exposure to a 500µm solution of glyphosate. Individuals from the Arizona glyphosate-resistant locality had increased copies of EPSPS in the range of 20 – 290-fold. This is the same mechanism previously identified in the Palmer amaranth lines from the southeastern US, therefore it is possible that resistance was introduced from elsewhere. DNA samples were collected for genotyping by sequencing (GBS) to perform single nucleotide polymorphism (SNP) calling, which will be used to determine the genetic structure of the different lines. Currently, neighbor joining trees and principle component analysis are being performed. This information about the evolution and migration of glyphosate resistance will be useful to design better strategies for herbicide resistance management.

Understanding the Genetic Evolution of Glyphosate Resistance in *Kochia scoparia* Populations. Karl Ravet*[1], Adrian Quicke[1], Shaheen Bibi[1], Eric Westra[1], Darci Giacomini[1], Mithila Jugulam[2], J Anita Dille[2], Phillip W. Stahlman[3], Patrick Tranel[4], Todd A. Gaines[1], Philip Westra[1], Dean Pettinga[1]; [1]Colorado State University, Fort Collins, CO, [2]Kansas State University, Manhattan, KS, [3]Kansas State University, Hays, KS, [4]University of Illinois, Urbana, IL (153)

The invasive weed *Kochia scoparia* has evolved glyphosate-resistance (GR) by massive gene amplification of the target gene 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), enabling the plants to survive the field rate of glyphosate application. Because of the intensive use of glyphosate and the heritability of the increased EPSPS gene copy number, GR in kochia has progressed on a rapid temporal scale, meaning that evolution of resistance occurred over the course of relatively few generations. As a result, GR in kochia is quickly gaining ground in a large part of the US and in the Prairie Provinces of Canada. By taking advantage of our ability to access GR and glyphosate-susceptible (GS) populations from throughout the US and Canada, we are conducting a population genetics study to 1) establish the dynamics of GR evolution through populations, and 2) to determine whether there was a single origin of GR *Kochia* that has then radiated throughout the region or whether GR emerged multiple times at different locations. For this work, we collected over the five past years more than 200 GR and GS *Kochia* populations from KS, CO, NE, WY, MT, and TX in the US, as well as populations from Canada. Populations are assessed for GR in greenhouse conditions at field rate glyphosate application. EPSPS copy number is quantified by genomic qPCR and Droplet Digital PCR (ddPCR). We developed a series of polymorphic Simple Sequence Repeat (SSR) DNA markers for determining relatedness of GR and GS populations. All together, our results should infer the number of origins of the resistance phenotype and the dynamics of evolution of GR throughout North America.

Kochia Control in Fallow with Winter versus Early Spring Preemergence Herbicide Applications. Randall S. Currie*[1], Curtis Thompson[2], Pat Geier[3]; [1]Kansas State Univ., Garden City, KS, [2]Kansas State, Manhattan, KS, [3]Kansas State, Garden city, KS (154)

ABSTRACT

With the advent of glyphosate-resistant kochia preemergence applications of dicamba in early spring have become standard practice. Cold and wet conditions often make it difficult to implement this method of control. Weather patterns often allow a mid winter application when the work load of applicators is light. Therefore, it was the objective of this research to compare various tank mixes with multiple modes of action known to provide excellent spring applied preemergence control of kochia at both winter and early spring timings. A balanced factorial of six herbicide tank mixes was applied at two timings. Herbicide treatments are abbreviated by the first letter of the active ingredient of each herbicides in the tank mix and were as follows: DA ,

dicamba+atrazine at 560+840 g ai/ha; SA, saflufenacil+atrazine at 49+840 g ai/ha; SAD, saflufenacil+atrazine+dicamba at 49+840+280 g ai/ha; PAD, pyroxasulfone+atrazine+dicamba at 146+560+280 g ai/ha; SIPD, saflufenacil+imazethapyr+pyroxasulfone+dicamba at 25+70+118+280 g ai/ha; or TIAD, thiencarbazone+isoxaflutole+atrazine+dicamba at 21+54+840+280 g ai/ha . These tank mixes were applied prior to emergence of kochia in during the first week of (December or spring (February 3 or March 10, 2015). Control was evaluated 8, 10, 13, 16, and 20 weeks after the spring treatment (WAT). The experiment was conducted near Garden City, and repeated at Tribune, Kansas. Each rating date was analyzed in a three factorial arrangement.All interactions of the six levels of herbicide tank mix, two timings, and two locations were tested. Although all factors interacted at the first rating date by 10 WAT no three way interactions were significant at the 5% level. Regression of the rate of decline in control over time was conducted for each of the application dates and for each of the herbicide tank mixes. Although the three way interactions at the first rating date were significant, control of tank mixes averaged over location and herbicide tank mix differed by only 3%. These interactions were ignored to facilitate the description of the rate of decay of the subsequent five rating dates which did not have significant three way integrations. At both application timings the response was very linear with R-squares of 0.91 and 0.95 for spring and winter treatments, respectively. At 8 WAT winter applications provided 81% compared to 84% control with the spring applications. At 20 WAT the rate of control of winter applications declined to 51% at a rate of 2.5% per week. In contrast spring applications declined to 64% at a rate of 1.6% per week. The decay in the level of control of individual tank mixes ranged from 1.8 to 2.6% per week. Treatment DA declined from 96.3% at 8 WAT to 67.5% at 20 WAT at a rate of 2.3% per week. Treatment SA declined from 94.3% at 8 WAT to 62.5% at 20 WAT at a rate of 2.6% per week. Treatment SAD declined from 96.3% at 8 WAT to 65.5% at 20 WAT at a rate of 2.5% per week. Treatment PAD declined from 98.4 % at 8 WAT to 74.3% at 20 WAT at a rate of 1.8% per week. Treatment SIPD declined from 96.4% at 8 WAT to 59.6% at 20 WAT at a rate of 2.8% per week. Treatment TIAD declined from 99.2% at 8 WAT to 74.4% at 20 WAT at a rate of 2.0% per week. Treatments PAD and TIAD were not significantly different at all rating dates. These treatments provided superior control to all other treatments at 8, 13, or 16 WAT (98, 95, and 89% control, respectively). All treatments provided greater than 94, 90, 86, 78 and 60% kochia control at 8, 10, 13, 16, or 20 WAT, respectively. Depending on the level of control desired at any point within the season, the cost of each treatment, the cost of retreatment and the weed spectrum expected at that time, any of these treatments could be a good value to individual growers. The opportunity cost of the time invested in application in each these seasons will vary greatly for each grower.

Evaluating the Effectiveness of Fall-Applied Herbicides for Kochia Management in Soybean in the Upper Great Plains. Mike H. Ostlie*[1], Brian M. Jenks[2], Gregory J. Endres[3]; [1]North Dakota State University, Carrington, ND, [2]North Dakota State University, Minot, ND, [3]NDSU, Carrington, ND (155)

Kochia can be one of the first weeds to emerge in the North Dakota growing season, with typical emergence dates ranging from late April to mid-May. The normal planting window for soybeans in the region is mid-May. Due to the early germination of kochia, soil-applied applications may not occur prior to kochia emergence. Alternatives include tank-mixing additional post-emergent products or applying earlier, maybe even the fall before soybeans. Three studies were conducted between 2013 and 2015 to evaluate the effectiveness of soybean soil-applied products as fall treatments, as well as evaluating effective spring tank-mix options. Results varied by year and location. In two environments Fierce and Spartan performed equally well in fall and spring, while in the third environment no product of equal rate performed as well fall-applied as spring-applied. In fact, at difference of at least 25% control was observed at the third environment between fall and spring applications. As expected, the length of residual was shorter for the fall-applied treatments compared to spring-applied. All spring-applied treatments were made post-emergent to kochia. Several combinations proved to be highly effective in the absence of glyphosate. Many of these combinations included metribuzin. Treatments without a lengthy residual noticeably stood out in 2015, when heavy rains occurred roughly 2 weeks after applications. Treatments without a strong residual component performed poorly. In general, there seems to be acceptable fall-applied options, with some risk, though a spring application will be much more predictable.

Glyphosate Induced Injury to Transgenic Herbicide-Tolerant Alfalfa under Cold Temperatures. Steve B. Orloff*[1], Robert Wilson[2], Brad Hanson[3]; [1]University of California, Yreka, CA, [2]University of California, Tulelake, CA, [3]Univ. of California, Davis, CA (156)

Glyphosate tolerant (GT) alfalfa has become an important part of weed managing programs for many alfalfa producers in western states. Considerable research was conducted before and shortly after its commercial release to evaluate both weed control and crop safety. The research indicated that properly timed applications of glyphosate provided excellent weed control with no perceptible crop injury, which was further confirmed by grower experience in commercial fields. However, in the spring of 2014 and 2015, significant crop injury was observed in GT alfalfa fields in the Scott Valley (Intermountain area of Northern California) following applications of glyphosate. After evaluating several fields with and without glyphosate injury, the anecdotal evidence suggested that cold temperatures after an application of glyphosate might be related to the observed injury. Yield was monitored in three commercial fields in the Scott Valley in 2015 by harvesting three treated and untreated areas in the affected GT alfalfa fields with a plot harvester and averaging the yield. Yield of the first cutting was reduced up to 0.8 tons/acre but no yield differences were noted in the subsequent cutting. A replicated field trial was conducted in early spring of 2015 at the Intermountain Research and Extension Center in Tulelake, CA when cold temperatures were expected. Established alfalfa was treated with glyphosate at two rates, 0.77 and 1.55 lb ae/A. Symptoms typically associated with frost injury (scattered individual shoots wilting that eventually turned necrotic) were noted in the glyphosate-treated plots but not the untreated controls. Alfalfa plants were visibly stunted and yield was reduced 0.3 and 0.4 tons/A for the 0.77 and 1.55 ae/A rates of glyphosate, respectively. There was no significant effect on second cutting yield. Four additional trials were conducted in the fall of 2015 where alfalfa was treated on weekly intervals from mid-September through October at the same rates as above. Within a week after some treatments, the same injury symptoms observed in the spring were found in some of the trials and, again, appeared to be related to cold temperatures around the time of application. The tips of affected shoots drooped in a "shepherd's crook" and eventually turned necrotic. Research results and field observations to date suggest that the injury may be related to the degree and number of frosts after application, the height of the alfalfa (tall alfalfa more prone to injury), and stand age (injury was has not been observed in seedling alfalfa or fields recently established). Initial greenhouse studies at UC Davis support field observations. However, additional research is needed in both the field and greenhouse to better understand the timing and degree of cold related to the observed injury, to determine the underlying mechanism of this interaction, and develop mitigation strategies for growers who use the GT alfalfa technology.

Dock (*Rumex* spp.) Control in Red Clover (*Trifolium pratense* L.) with Asulam and 2,4-DB.
Kyle Roerig*[1], Andrew Hulting[2], Daniel W. Curtis[1], Carol Mallory-Smith[1]; [1]Oregon State University, Corvallis, OR,[2]Associate Professor, Corvallis, OR (157)

Dock species (*Rumex* spp.) are persistent, competitive perennials in the Polygonaceae family that develop a robust tap root. Dock continues to be a problematic weed in clover grown for seed. Currently registered herbicides for use in clover seed production provide poor control of dock species. Asulam is a group 18 (DHP inhibitor) herbicide registered for use alfalfa grown for seed and 2,4-DB is a group 4 herbicide (synthetic auxin) registered for use in several legume crops. Trials were conducted in commercially grown red clover fields in 2013 (asulam only), 2014 and 2015 infested with a mixture of curly dock (*Rumex crispus* L.) and broadleaf dock (*Rumex obtusifolius* L.) to evaluate crop safety and dock control. Asulam application rate was 1.68 kg ai/ha and 2,4-DB rates ranged from 0.56-1.68 kg ha. Visual ratings of dock control were greatest and dock seed heads counts were lowest when 2,4-DB or asulam was applied in March. Control with asulam and 2,4-DB was equivalent and neither reduced seed yield at p-value 0.05. Split application did not improve control of dock species with either asulam or 2,4-DB. Some leaf cupping was observed following the 2,4-DB application, but did not result in a decrease in clover vigor or yield. 2,4-DB labels caution against the addition of a non-ionic surfactant in legumes due to increased risk of crop injury. In this trial, no additional injury was observed when non-ionic surfactant was added to 2,4-DB. Additionally, there were no differences in clover injury or yield and dock control between the 1.12 and 1.68 kg ha rates of 2,4-DB. Clover injury was unacceptable when asulam was applied in April or later. In the 2015 trial, the late January and early March timings seem to be within the optimal window of application for good dock control and acceptable crop injury. No treatments in this trial caused a reduction in clover seed yield or seed quality as measured by clover seed germination. Data from these studies indicate that 2,4-DB and asulam provide good control of dock and are safe for use on clover.

PROJECT 4: TEACHING AND TECHNOLOGY TRANSFER

Using the 2016 Guide for Weed, Disease and Insect Management in Nebraska (EC130) to Improve Pesticide Efficacy and to Manage Spray Drift. Robert N. Klein*; University of Nebraska, North Platte, NE (091)

The 2016 Guide (EC130) has three pages, double columns on what is listed on the herbicide labels for either recommended or required spray droplet size (or sizes) for application. Along with the droplet size is listed the carrier rate (GPA) on the label. One additional page with double columns lists the information for insecticides and fungicides.

To assist applicators in nozzle tip selection and pressure to obtain the recommended or required spray droplet size, the Guide (EC130) has 10 charts: medium, coarse, very coarse at 10 GPA; extremely coarse and ultra coarse at 15 GPA; and medium, coarse, very coarse, extremely coarse and ultra coarse spray droplet sizes at 20 GPA. Two additional charts include glyphosate at 10 GPA and fungicide and insecticides at 15 and 20 GPA. The charts include 15, 20 and 30 inch nozzle spacing and speeds at 6, 7, 8, 10, 12 and 14 mph. One of the charts follows.

For Extremely Coarse (XC) Spray Droplet Size 15 GPA						
		Nozzle Spacing				
Speed mph	**Rate gpm**	**20-inch**	**Rate gpm**	**15-inch**	**Rate gpm**	**30-inch**
6	0.303	AIXR11004@23psi	0.227	AIXR11003@23psi	0.455	AIXR11005@33psi
7	0.354	AIXR11004@31psi**	0.265	AIXR11004@17psi*	0.530	AIXR11006@31psi
8	0.404	AIXR11005@26psi	0.303	AIXR11004@23psi	0.606	AIC11006-VK@41psi
10	0.505	AIXR11006@28psi	0.379	AIXR11005@23psi	0.758	AIC11006-VK@64psi**
12	0.606	AIC11006-VK@41psi	0.455	AIXR11006@23psi	0.909	AIC11008-VK@52psi
14	0.707	AIC11006-VK@56psi	0.530	AIXR11006@31psi	1.061	AIC11010-VK@45psi*

*Just into the next larger spray drop size with water - many pesticides and additives reduce the spray drop

**Just into spray drop size

Glyphosate: A Modern Day Drifter. Morgan D. Hanson*[1], Kirk A. Howatt[1], William T. Cobb[2]; [1]North Dakota State University, Fargo, ND, [2]Cobb Consulting Services, Kennewick, WA (092)

The expansion of herbicide-resistant crop production has increased the potential for off-target movement to sensitive crops. Field experiments were evaluated to determine wheat (*Triticum* *aestivum*) response to microrate applications to simulate glyphosate drift. The objective of these experiments was to indicate at which glyphosate rate did visible injury occur and how this injury affected yield. Glyphosate treatments ranging from 0 to 70 g ha^{-1} were applied to wheat at four different growth stages: two-leaf, four-leaf, flag leaf, and anthesis. Treatments were visually evaluated based on a 0 to 100% scale 28 days after treatment and yield was recorded after harvest. Visible injury, 5%, was observed with glyphosate rates as low as 0.7 g ha^{-1} that caused approximately 20% yield reduction. Very low rates of glyphosate had less effect on wheat nearing anthesis compared to plants exposed at earlier application timings. Additional studies demonstrated that glyphosate accumulated in the grain of wheat that survived glyphosate drift. North Dakota State University has received funding to correlate yield loss with glyphosate residue in tissue.

Glyphosate Residue, Looking For Love In all The Wrong Places. William T. Cobb*; Cobb Consulting Services, Kennewick, WA (093)

Glyphosate use in commercial agriculture continues to increase every year especially with ever the ever increasing numbers of RR crops (alfalfa, corn, canola, cotton, soybeans and sugar beets). Although glyphosate has no greater propensity to move off target than most other herbicide compounds, glyphosate's ever increasing use seemingly results in more non-RR crops being unintentionally contaminated via drift, sprayer contamination or misapplication almost every year. Glyphosate has a multitude of various crop residue tolerances, consequently food safety concerns resulting from unintentional exposure to glyphosate are rarely an issue. However, unintentional exposure of crops to glyphosate that are intended for use as seed, raise questions as to the fitness of the exposed seed crops for their intended use. Potatoes are an excellent example; late season exposure of "mother plants" to glyphosate results in detectable levels of glyphosate residue in the daughter tubers at harvest. If these daughter tubers are used for seed, significant aberrations of the morphology of the daughter plants are usually evident including non-emergence, delayed emergence, multiple stems from each tuber eye, reduced plant vigor as well as reduced crop yield and quality. Likewise, exposure of winter wheat plants to glyphosate in the fall or spring of the crop year, often result in detectable residue in the wheat kernel at harvest. Dry bean plants exposed to sub-lethal dosages of glyphosate following emergence can also result in glyphosate residue in the mature bean at harvest.

Are All High Surfactant Oil Concentrate Adjuvants Created Equal? Devin A. Wirth*[1], Rich Zollinger[2], Jason W. Adams[1]; [1]NDSU, Fargo, ND, [2]North Dakota State University, Fargo, ND (094)

High surfactant oil concentrate (HSOC) adjuvants were developed to enhance lipophilic herbicides without antagonizing hydrophilic herbicides. They can be either methylated seed oil based (HSMOC) or petroleum oil concentrate based (HSPOC). High surfactant oil concentrate adjuvants contain a minimum of 50% oil with 25 to 50% emulsifier surfactant. The purpose of this study was to screen multiple HSOC adjuvants to quantify their relative effectiveness when mixed with glyphosate and either dicamba or tembotrione. Reduced rates of glyphosate at 473 g ai ha^{-1}, dicamba at 214 g ha^{-1}, and tembotrione at 46 g ha^{-1}were applied with HSOC adjuvants at 1170 ml ha^{-1}. The trial was a randomized complete block design with three replications. Plot dimensions were 3 by 12 m with herbicides applied to the center 2 m. Treatments were applied across four indicator species that were sown perpendicular to the plots. Treatments were averaged across all species. HSMOC adjuvants increased herbicidal control of species more than HSPOC adjuvants. Statistically there was similar species control within all HSMOC adjuvants. Likewise, there was similar species control within all HSPOC adjuvants.

Is Early Detection & Rapid Response the Only Viable Approach for Proactive Herbicide Resistance Management? Andrew R. Kniss*[1], Brian A. Mealor[2], Gustavo M. Sbatella[3]; [1]University of Wyoming, Laramie, WY, [2]University of Wyoming, Sheridan, WY, [3]University of Wyoming, Powell, WY (095)

Abstract not available

The Wyoming Restoration Challenge: Participatory Learning in the Information Age. Brian A. Mealor*[1], Julia M. Workman[2], Beth Fowers[2], Clay W. Wood[2]; [1]University of Wyoming, Sheridan, WY, [2]University of Wyoming, Laramie, WY (096)

Millions of acres of western rangelands are negatively impacted by invasive species, and downy brome (*Bromus tectorum*) is one of the most widespread. Hundreds of research papers have been published on its ecology and management, yet land managers around the West are still uncertain of the most effective, cost-efficient methods to restore downy brome-dominated systems to a higher-functioning status. In 2015, we issued an open invitation for teams to enter a competition to determine who could best restore a degraded pasture with a high amount of downy brome. Objectives of this participatory learning project are to: 1) increase land managers' knowledge about techniques for restoring weed-dominated pastures, 2) build awareness of the importance of managing invasive weeds, 3) evaluate various methods for restoring degraded pasture infested with downy brome and other annual weeds, 4) share information with various audiences regarding relative performance of those methods, and 5) encourage friendly competition among teams. Each team was randomly assigned one ¼ acre plot and were given access to plots in April 2015. Their results will be evaluated annually through fall 2017. Any legal methods for removing downy brome and reestablishing a diverse, desirable plant community are allowed. Teams will be evaluated on multiple categories including productivity, diversity, costs of implementation, scalability, and educational program development. As approaches are implemented, the site becomes analogous to a traditional extension demonstration plot, with side-by-side restoration tactics available for direct comparison. The most efficient way to follow the competition is at www.facebok.com/WYrestorationchallenge/.

Weed Science in the Twitterverse: Education, Conflict, and Pornbots. Lynn M. Sosnoskie*; University of California, Davis, CA (097)

Abstract not available

PROJECT 5: BASIC BIOLOGY AND ECOLOGY

An *in vitro* System for Predicting Herbicide Subcellular Partitioning. Eric L. Patterson*, Scott J. Nissen, Todd Gaines; Colorado State University, Fort Collins, CO (116)

A complete understanding of herbicide chemical properties is essential to predict their behavior in plants. All herbicides must pass one or more membranes to reach their target enzyme, and therefore the process by which a herbicide crosses a membrane will partially determine its effectiveness. Small molecule diffusion and subcellular partitioning is extremely difficult to study *in vivo*. In an attempt to increase the tools to study passive herbicide movement, we have modified a three-phase partitioning system that mimics biological semipermeable membranes, allowing us to study and measure compartment partitioning. Additionally, we are able to empirically measure important chemical phenomena such as acid trapping, concentration based diffusion, and hydrophobicity. This system is also able to predict the effectiveness of additional apoplast acidification for any given herbicide and whether minor changes in pH will affect herbicide diffusion. To test our apparatus, we studied clopyralid, sulfentrazone, 2,4-D, and glyphosate. These four herbicides vary substantially for pKa and K_{ow} and therefore are a robust test of our apparatus and its capabilities. For the most part, our four herbicides partition predictably based on their pKa and K_{ow}; however, we were able to detect a higher affinity for the organic layer for 2,4 D when it is protonated then initially predicted. Our findings illustrate the value of our system to provide useful and novel information about herbicide subcellular behavior.

High Resolution Physical Mapping of EPSPS Copies in Glyphosate-Resistant *Amaranthus* species. Mithila Jugulam*, Karthik Putta, Dal-Hoe Koo, Dallas E. Peterson, Bernd Friebe, Bikram S. Gill; Kansas State University, Manhattan, KS (117)

The *EPSPS* (5-enopyruvlyshikimate-3-phosphate synthase) gene amplification, conferring resistance to herbicides in agricultural weeds is a novel mechanism and was first documented in glyphosate-resistant (GR) *Amaranthus palmeri,* and later in *A. tuberculatus*, two economically important and troublesome weeds of US agriculture. However, little is known about the mechanisms and cytogenetic consequences associated with *EPSPS* gene amplification in these two GR Amaranthus species. Using molecular cytogenetic maps of the *EPSPS* gene in glyphosate-susceptible (GS) and GR *A. palmeri* and *A. tunerculatus*, we demonstrate for the first time, that the initial amplification of *EPSPS* gene can be mediated by unequal recombination between homologous chromosomes and subsequently, possibly via transposon-mediated amplification. Additionally, in *A. tuberculatus*, we also found the presence of circular extrachromosomal DNA bearing amplified *EPSPS* copies (CEBA) which are stable in mitosis, but preferentially transmitted to the next generation. This suggests a stepwise amplification of *EPSPS* genes can occur in GR Amaranthus species. Furthermore, we also propose that the massive increase in *EPSPS* copies may have occurred as a result of genome duplication in *A. palmeri*. Our results reveal that the transposable element-mediated *EPSPS* gene amplification, as suggested previously, is not the sole mechanism involved in gene amplification in Amaranthus species.

Spatial Genetic Structure and Glyphosate Resistance in *Lolium perenne* ssp. Multiflorum (Italian ryegrass) in California Orchards and Vineyards. Elizabeth Karn*, Marie Jasieniuk; University of California-Davis, Davis, CA (118)

Resistance to glyphosate has become widespread in Italian ryegrass *(Lolium perenne* ssp. multiflorum) in northern California, and has recently been identified in Lake and Sonoma Counties. The objective of this study was to examine the population genetics of Italian ryegrass to gain an understanding of whether population structuring and differentiation exists in this obligately-outcrossing weed in California, and to use this information combined with glyphosate resistance status to examine how glyphosate resistance may be evolving in Italian ryegrass in the region. Seeds and leaf tissue were collected from 20 to 40 parents in each of 14 populations. Between 55 and 212 offspring per population were tested for resistance to glyphosate in a greenhouse using cloned plants. The percentage of plants surviving 1681 g ae ha^{-1} (1.5 lbs/acre) glyphosate application ranged from 9 to 89% among populations. DNA was extracted from the parents and genotyped at 12 microsatellite loci. All sampled populations of Italian ryegrass had a large number of alleles and high allelic richness, indicating high genetic diversity. Observed heterozygosity was lower than expected under Hardy-Weinberg equilibrium in all populations. PCoA showed genetically similar populations grouping together by geographical region. However, an AMOVA revealed that most genetic variation was distributed among individuals within populations rather than among regions or sampled populations. STRUCTURE analysis revealed two distinct genetic clusters within the Italian ryegrass sampled. Glyphosate resistant individuals assigned to each cluster. Italian ryegrass in northern California contains a high frequency of resistance in some areas, with evidence of high genetic diversity and population structuring across the region.

Molecular and Genomic Weed Science Research at Colorado State University. Philip Westra*, Todd Gaines, Franck Dayan; Colorado State University, Fort Collins, CO (119)

Abstract not available

Experimental Methods for Confirming Resistance to Synthetic Auxin Herbicides. Carl W. Coburn*, Andrew R. Kniss; University of Wyoming, Laramie, WY (120)

The selectivity index (SI) is a measure of herbicide resistance, and it is important to understand how experimental factors may influence it. Greenhouse experiments were conducted to determine the effect of pot size, application timing, and response variable on the SI of dicamba-susceptible and –resistant *Kochia scoparia* (kochia). Kochia biotypes were planted in the greenhouse in four different pot sizes (750, 1200, 1500, and 3800 cm^3) and were treated pre emergence (PRE) or post emergence (POST) with dicamba. PRE rates for the susceptible and resistant biotypes ranged from 0 to 175 and 0 to 700 g ae ha^{-1}, respectively. POST rates for the susceptible and resistant biotypes ranged from 0 to 3500 and 0 to 7000 g ae ha^{-1}, respectively. A log-logistic model was used to quantify the response of kochia biotypes to dicamba. Injury was assessed visually 30 days after treatment (DAT) for both application timings. Above and below ground biomass and mortality were assessed 30 DAT for POST treatments while above ground biomass and emergence were assessed 60 DAT for PRE treatments. For visual injury and above ground biomass, the ED_{50} (dose resulting in 50% response) was lower for PRE compared to POST treatments for all pot sizes. Mortality resulted in the highest ED_{50} estimates and the lowest variability in SI for POST treatments. Visual injury and above ground biomass resulted in similar ED_{50} and SI values for PRE treatments.

Using Multiple Sequencing Platforms to Assemble the *Kochia scoparia* Genome. Todd A. Gaines*[1], Eric L. Patterson[1], Karl Ravet[1], Patrick Tranel[2], Philip Westra1; [1]Colorado State University, Fort Collins, CO, [2]University of Illinois, Urbana, IL (121)

To better integrate weed biology in future agriculture 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. Our research team has begun the effort of sequencing the *Kochia scoparia* genome. *K. scoparia* is a member of the Chenopodiaceae family, a sister taxon to 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, complex, and malleable genome of *K. scoparia* makes sequencing and genome assembly an interesting challenge. It appears that the large genome (haploid size of 1.0-1.3 Gb) may be due to a recent polyploidy event in the Chenopodiaceae lineage, resulting in large highly repetitive regions that are difficult to resolve without more advanced approaches to sequencing. We are utilizing both Illumina and PacBio sequencing technologies to conduct a hybrid-platform draft assembly of the *K. scoparia* genome. Our initial findings demonstrate the challenges in assembling a complex weedy species genome and potential for using cutting-edge molecular tools to improve our understanding of weed biology and weedy traits.

Using RNA-Seq to Explore Dicamba Resistance Mechanisms in *Kochia scoparia*. Dean Pettinga*, Philip Westra, Todd Gaines; [1]Colorado State University, Fort Collins, CO (122)

Resistance to dicamba (a synthetic auxin) has been documented in *Kochia scoparia* populations since 1994, but the mechanism of resistance remains elusive. The exact mechanism of action for this herbicide is also unknown, which poses an additional challenge. Multiple auxin signaling pathways could be involved in target site resistance while non-target site mechanisms including altered herbicide metabolism, sequestration, absorption, or translocation could also contribute to resistance. To address all these mechanisms, an RNA-Seq approach was used to investigate transcriptome gene expression patterns of dicamba-resistant (R) and -susceptible (S) inbred kochia lines. Apical meristematic tissue of greenhouse grown plants was extracted from untreated R and S individuals, and from R and S individuals 12 hours after treatment with dicamba. mRNA was isolated from extracted tissue and used to construct cDNA libraries which were sequenced with 4 lanes on the Illumina HiSeq 2500 platform. Reads were aligned to a reference transcriptome and gene expression profiles of R and S lines were compared. Quality control and significance cutoffs were employed, identifying 846 differentially expressed transcripts as possibly related to resistance mechanisms and/or response to dicamba.

Economic Feasibility of Supplementing Cornstalk Grazing with Fall-Seeded Forage Crops in Southeast Wyoming. Jenna Meeks*[1], Brian P. Lee[1], Brian A. Mealor[2], Steve I. Paisley[3], Andrew R. Kniss[4];[1]University of Wyoming, Lingle, WY, [2]University of Wyoming, Sheridan, WY, [3]University of Wyoming, Lngle, WY, [4]University of Wyoming, Laramie, WY (138)

Cattle in southeastern Wyoming commonly graze cornstalks during winter months. Grazing corn residue is typically less expensive than feeding stored forages such as alfalfa hay, partly due to lower feed quality. Interseeding forage crops into standing corn can extend the grazing season for corn stalks and increase feed quality. A field study was initiated in the fall of 2013 and repeated in 2014 to determine the impact of seeding date on forage crop biomass production for winter grazing. Six planting dates were arranged in a randomized complete block design with 4 replicates. The seed mixture included annual ryegrass, crimson clover, rapeseed, turnip, and radish aerially seeded at 13 kg/ha. Seeding occurred at 10 to 21 d intervals between September 2 and October 30 in 2013 and July 14 and October 13 in 2014. Aboveground biomass was collected from each plot to estimate forage crop biomass. Corn yield was not significantly impacted forage crop, regardless of seeding date. The earliest seeding date produced 160 kg/ha or 0.44 animal unit months (AUM) when sampled in November of 2014. For December grazing, the earliest seeding date produced 0.22 and 0.24 AUM in 2013 and 2014, respectively. Later seeding dates reduced AUM production in both years. Seed and aerial application cost ranged from $73 to $83 per hectare, making the cost of this seed mixture between $165 to $188 per AUM.

A Depsipeptide from the Pathogenic Fungi *Burkholderia* sp. A396 Targets Plant Histone Deacetylases. Franck E. Dayan*[1], Daniel K. Owens[2], Caio A. Carbonari[3], Giovanna L. Gomes[3], Ratnakar Asolkar[4], Louis Boddy[4]; [1]Colorado State University, Fort Collins, CO, [2]USDA-ARS, University, MS, [3]University of Sao Paulo, Botucatu, Brazil, [4]Marrone BioInnovation, Davis, CA (139)

MBI-010 MW 540, a 16-membered cyclic depsipeptide bridged by a 15-membered macrocyclic disulfide, has been isolated by Marrone BioInnovations from one of their in-house microbial extracts of*Burkholderia* sp. A396. The herbicidal activity of MBI-010 MW 540 was discovered through a bioactivity-guided isolation of the microbial broth. It causes necrosis of the treated plants similar to that observed with compounds that inhibits glutamine synthetase (GS). However, MBI-010 MR540 does not inhibit GS activity. We discovered that this natural phytotoxin inhibits histone deacetylase (HDAC). Histone acetylation and deacetylation by histone acetylases and deacetylases regulates epigenetic transcriptional activation and silencing in eukaryotes. These regulatory partner enzymes are an important class of global transcriptional regulators that play crucial roles in plant development, defense, and adaptation. Inhibition of HDAC has lethal consequences in plants. Reduction of the disulfide bridge of MBI-010 MW 540 liberates a long sulfhydryl side chain that extends in the cavity of HDAC and binds reversibly to the catalytic domain and renders the enzyme inactive.

Determining Seed Retention of Key Annual Weeds at Wheat Harvest. Neeta Soni*[1], Todd A. Gaines[1], Philip Westra[1], Scott J. Nissen[1], Michael J. Walsh[2]; [1]Colorado State University, Fort Collins, CO, [3]University of Western Australia, Perth, Australia (140)

Annual winter grasses such as feral rye (*Secale cereale*), downy brome (*Bromus tectorum*), and jointed goatgrass (*Aegilops cylindrica*) are the major problematic grass weed species in Colorado wheat fields. Currently, those species are managed with herbicides and crop rotation. A complementary weed control tool is needed to diversify weed management techniques. One approach is harvest weed seed control (HWSC). HWSC methods destroy, burn or remove weed seeds from the field. Target weed species need to retain seed at harvest height for HWSC to be effective. Feral rye, downy brome, and jointed goatgrass have a similar growth habit as wheat. These species have similar height and reach maturity at wheat harvest. Therefore, we hypothesized that the majority of seeds from these weed species are retained in the harvestable wheat fraction of the canopy. Our main objective was to quantify seed retention by comparing the amount of weed seeds retained in the upper wheat canopy with the shattered seed on the soil surface. To accomplish this objective, 21 wheat field located around eastern Colorado were sampled. In each field, 4 replicate samples were collected containing the weed species present at the site. There were 14, 6, and 7 fields containing feral rye, jointed goatgrass, and downy brome, respectively. Plant height, density and seed amount were quantified per weed species to compare retained weed seeds in the above 15 cm of wheat with shattered weed seeds. In addition, biomass and grain yield were recorded for wheat. Results showed that 75% of downy brome and jointed goat seed, and 85% feral rye seed remained in the upper section of the wheat canopy. As an integrated pest management practice, implementation of HWSC approaches substantially decrease weed pressure for the next wheat season. Potential benefits of HWSC include reduced herbicide use, improved management of herbicide resistance, and reduced production costs in the long term for wheat fields.

Response of Light-Grown *Beta vulgaris* to Reflected Far-red Light. Albert T. Adjesiwor*, Thomas J. Schambow, Andrew R. Kniss; University of Wyoming, Laramie, WY (141)

Photosynthetic pigments absorb red (R) light and reflect far-red (FR) light. Thus, light reflected from vegetation has a reduced R to FR light ratio (R:FR). Phytochromes enable plants to detect changes in R:FR and use this as a cue to perceive proximity of neighboring plants. To avoid perceived impending competition, plants initiate morphological and physiological responses that can affect growth and yield in the absence of resource competition. Rapid vertical stem growth and reduced branching are common responses to altered R:FR. *B. vulgaris* is a rosette-forming plant with limited vertical stem extension when grown as annual; therefore, little is known about how *B. vulgaris* responds to altered R:FR, and the implications on growth and yield. We evaluated effects of reflected R:FR from Kentucky bluegrass on growth and yield of *B. vulgaris*. Grass was clipped frequently to prevent shading and competition for light. Roots of grasses were isolated from *B. vulgaris* to ensure there was no competition for water or nutrients. The grass treatment modified *B. vulgaris* petiole to leaf length ratio and significantly reduced number of leaves, leaf area, root fresh weight, and top fresh weight. *B. vulgaris* produced, on average, 4 fewer leaves in the grass treatment compared to the control (no grass) at harvest (73 days after planting). Similarly, the grass treatment reduced top fresh weight, leaf area and root fresh weight by 27, 27, and 21% respectively. These results showed reflected FR light can reduce growth and yield of *B. vulgaris* in the absence of resource competition.

Potential Effects of Harvest Weed Seed Control on Wild Oat Populations Based on Demographic Modelling. Breanne Tidemann*[1], Linda M. Hall[1], K. Neil Harker[2], Brendan Alexander[1], Kristina Polziehn[3];[1]University of Alberta, Edmonton, AB, [2]Agriculture and Agri-Food Canada, Lacombe, AB, [3]Axiom Agronomy Ltd., Edmonton, AB (142)

Wild oat is a globally problematic weed species that requires new management techniques to manage herbicide resistance; Harvest Weed Seed Control (HWSC) may be an option. Data collected in rotational field studies in Alberta under management regime extremes (no integrated weed management, no herbicide to high integrated weed management, full herbicide) was used to parameterize a periodic matrix model. Elasticity analysis was conducted in addition to an analysis where the model equation was rearranged, population growth rate (λ) was designated and the equation solved for survival of newly shed seed (s_{new}). All populations had λ>1, or growing populations. Elasticity analysis indicated that population growth rate is most highly elastic to the over-winter seed-bank (E_{sw}= 1), followed by seedling survival, fecundity, and survival of newly shed seed (0.63-0.86 across treatments). The latter may be the most accessible life-cycle transition for management. However, decreasing the proportion of newly shed seeds that survives was the most effective and available control strategy only until reduced to 0.1-0.3. Further reductions are less impactful; the seed-bank during the growing season becomes more critical. When averaged across treatments, >80% of newly shed seed must be eliminated to stop the population from growing, resulting in a stable population, but not a decline. Due to pre-harvest seed shattering, causing wild oat populations to decline by using HWSC alone to impact the survival of newly shed seeds will likely not be effective; new management techniques to use in combination with HWSC and IWM strategies are needed.

Fire and Fire Management Impacts on Cheatgrass (*Bromus tectorum*) in Montana. Erik A. Lehnhoff*[1], Tim F. Seipel[2], Lisa Rew[2]; [1]New Mexico State University, Las Cruces, NM, [2]Montana State University, Bozeman, MT (143)

Exotic plants can interact with their environment through positive feedback cycles to perpetuate themselves. *Bromus tectorum* (cheatgrass) in much of the Intermountain West of the USA is reported to have a positive feedback cycle with fire. Its presence may increase fuel loads which increase fire frequency and severity to the detriment of native species while providing additional colonizable habitat for itself. We investigated the effects of one natural fire and one prescribed burn in Montana, USA on *B. tectorum* populations and the native plant communities. Response to fire was similar at both sites. One year after the fires, there were minimal differences in *B. tectorum* cover between burned and unburned plots, with fire increasing *B. tectorum* cover from 3% to 5%. Two years post-fire, *B. tectorum* increased to 8%. During the natural fire, a fire break was installed to prevent fire spread. Two years-post fire, *B. tectorum* cover along the fire break was more than 300% greater than in the burned or unburned areas. Fire resulted in minimal plant species shifts, with annual and non-native species each increasing by <5% cover. Principal coordinates analysis suggests that plant communities in the burned areas are becoming more similar to the unburned communities over time. However, the fire break plant community is becoming even less similar to the unburned communities. Our data do not support the idea that fire promotes *B. tectorum* dominance. Furthermore, data show that in Montana fire containment has a much greater negative impact on the plant community than fire does, and is not recommended as a management tool if the goal is to limit *B. tectorum* spread and dominance.

Gene Flow Between Canola and Totsoi. Nami Wada*[1], Bumkyu Lee[2], Soo In Sohn[2], Kijong Lee[2], Carol Mallory-Smith[1]; [1]Oregon State University, Corvallis, OR, [2]National Academy of Agricultural Science, Jeonju-si, South Korea (144)

Previous studies have confirmed rapeseed canola (*Brassica napus*) is capable of producing hybrid offspring with a number of related *Brassicaceae* species. Within the species *Brassica rapa*, there is a great deal of variation in plant form, and many subspecies are important vegetables. Gene flow between *B. napus* and *B. rapa* occurs with the crossing rate dependent on the compatibility with the subspecies.One of the *Brassica rapa* vegetables of concern for crossing with canola is a Chinese cabbage, tatsoi (*Brassica rapa var. rosularis*). Therefore, a small-scale field experiment was designed to assess the frequency of the pollen-mediated gene flow occurrence between imidazolinone resistant canola (paternal) and tatsoi (maternal) at the distances of 0 to 35 m in four directions from the pollen source. Hybridization was confirmed by screening the recipient progeny with an application of imazethapyr followed by PCR with a species-specific primer, BoKAH45TR, to detect the paternal genetic marker. Hybridization was observed at every distance with the highest crossing rate of 5.8% at 0 m, and with rates ranging from 0.6 to 1.8%. Most hybridization occurred within a 5 m distance on north and west of the pollen source. However, some patches of higher crossing frequency were observed over the distances on south and east, suggesting both wind direction and insect pollinators may contribute to the pollen dispersal. This study confirmed

the production of viable offspring between canola and tatsoi, which in certain markets would be of concern if the canola was genetically engineered.

Herbicide Resistance in Hairy Fleabane: the Effects of Region, Season, Size and Methodology on Expression. Lynn M. Sosnoskie*, Bradley D. Hanson; [1]University of California-Davis, Davis, CA (145)

Weed pressure, and the resulting competition for water and nutrients, can significantly impact orchard establishment. In commercially bearing orchards, weeds must be managed to improve irrigation efficiency, provide equipment access for other pesticide applications, and ensure that nuts can be harvested effectively and economically. Furthermore, weeds may harbor insect, vertebrate, and pathogenic pests that can significantly reduce tree health. Pesticide use data suggest that many orchards are being treated multiple times each year with both pre- and post-emergence herbicides. Unfortunately, complete weed control is not assured, even when the most effective chemical programs are employed.

Glyphosate is the principal herbicide in high-value tree nut [*e.g.* almonds (*Prunus dulcis* (Mill.) D.A. Webb.), pistachios (*Pistacia vera* L.), walnuts (*Juglans regia* L.)], grape (*Vitis vinifera* L.) and stone fruit [*e.g.*peach (*Prunus persica* (L.) Batsch.), dried plums (*Prunus domestica* L.)] production systems. Glyphosate resistance in California populations of hairy fleabane (*C. bonariensis*), a non-native, winter annual weed in the Asteraceae family, was first reported in 2008; results from a subsequent *in vivo* shikimate accumulation assay revealed that 79% of hairy fleabane accessions (*n* = 122) collected from California's Central Valley exhibited some degree of resistance. Additional research conducted at the University of California – Davis has since demonstrated that the expression of glyphosate resistance in hairy fleabane can vary, significantly, based on the time of year when studies are conducted, plant size at time of application, and when observations occur post-treatment.

In 2010 and 2011, greenhouse studies were conducted to determine the levels of glyphosate resistance in hairy fleabane collected from orchards and vineyards distributed throughout the Central Valley of California. Although glyphosate resistance was widely distributed, results from non-linear regression analyses showed that the responses varied among the screened samples. With respect to growth reduction (GR_{50}), hairy fleabane accessions were between 5- and 18-times more resistant to glyphosate as compared to a susceptible population. Additional analyses indicated that external environmental factors were also influencing glyphosate resistance. Seedlots from nine regions in California were screened across two seasons; plants that were evaluated between May and August were 1- to 16-times more resistant to glyphosate, with respect to injury and biomass reduction, than those that were evaluated between November and February. These results are in agreement with published work indicating that glyphosate sensitivity can be re-established in *Conyza* species under certain conditions, such as low temperatures.

Results from an experiment describing the effects of plant size on subsequent glyphosate injury showed that hairy fleabane treated at the rosette or bolting stages were more likely to be significantly injured by herbicide applications than plants that were budding or flowering at the time of treatment. Greater injury and delayed compensatory growth were also associated with reductions in seedhead and flower bud production. For example, glyphosate-susceptible hairy fleabane plants that were bolting or budding at the time of glyphosate applications (rates of either 840 or 1680 g/ha) did not produce mature seedheads at 9 WAT; plants that were beginning to flower at the time of herbicide applications produced 25-30 mature seedheads at 9 WAT. Although this represented a significant reduction in reproductive potential relative to the untreated check (500 seedheads at 9 WAT), seed produced by rogue, uncontrolled plants can impact weed management success in subsequent seasons. As such, weed management should focus on preventing additions to the seedbank.

The type and timing of injury estimates may also affect how glyphosate resistance is assessed perceived. Results from a cursory study in the greenhouse showed that glyphosate injury on glyphosate resistant hairy fleabane was generally greater at the 28 DAT observation date as compared to 14 and 42 DAT. Alternately, plant biomass (relative to the untreated check) at 28 DAT was lower than at 14 and 42 DAT. Glyphosate injury symptoms were not fully developed at day 14, whereas plant recovery was occurring by day 42. The response of the susceptible check was less variable with time; these differences (among and within biotypes) suggest that comparisons of dose response models may fluctuate according to observation date.

Mechanism of ALS inhibitor resistance in Shepherd's-purse (Capsella bursa-pastoris).
Rachel J. Zuger*[1], Louise Lorent[1], Jeanette A. Rodriguez[2], Caleb C. Squires[1], Nevin C. Lawrence[3], Amber L. Hauvermale[1], Ian C. Burke[1]; [1]Washington State University, Pullman, WA, [2]Heritage University, Prosser, WA, [3]University of Nebraska - Lincoln, Scottsbluff, NE (146)

Shepherd's-purse [*Capsella bursa-pastoris* (L.) Medik] is an annual broadleaf weed commonly found in small grain fields in the Pacific Northwest. Shepherd's-purse is not commonly targeted for spray applications. However, many acetolactate synthase (ALS) inhibiting herbicides control shepherd's-purse, selecting for resistance. A population of shepherd's-purse in eastern Washington was suspected of ALS-inhibitor resistance after surviving a commercial application of pyroxsulam at 18.4 g ai ha^{-1} with an nonionic surfactant at 0.5% v v^{-1}. A dose response assay confirmed the suspected-resistant biotype (GD_{50} = 2350 g ai ha^{-1}) is 1,011 times more resistant to pyroxsulam than the known susceptible biotype (GD_{50} = 4.647 g ai ha^{-1}, 0.002 g ai ha^{-1}). The resistant biotype was tested for cross-resistance to four ALS-inhibiting herbicides in three chemical classes: imazamox, propoxycarbazone, mesosulfuron, and thifensulfuron applied at maximum field rates in wheat. Results confirmed cross-resistance in the resistant biotype to imidazolinones, sulfonylureas, sulfonylaminocarbonyltriazolinones, and triazolopyrimidines, strongly suggesting target site resistance. The biotype was not resistant due to increased metabolism, decreased absorption, or translocation of pyroxsulam compared to the susceptible biotype. Attempts at sequencing have detected a possible point mutation, an amino acid substitution at Trp_{574} to Leu. Target site resistance appears to be the likely mechanism conferring ALS-inhibitor resistance in the shepherd's-purse biotype. Although pyroxsulam-resistant shepherd's-purse is present in the Pacific Northwest, the abundance and distribution of the resistant biotype is unknown. If resistance is common, shepherd's-purse has the potential to be a serious weed due to its capacity to produce large quantities of long-lived seed.

EDUCATION & REGULATORY SECTION

Weeds Up Close and Personal: Update. Robert F. Norris*; University of California, Davis, CA (129)

Focus stacking has eliminated the problem of limited depth of field in close-up photography. Initially the 'stack' of photographs was taken using manually adjusted focus points or through the use of software that controlled the focus motor built into the camera or the lens. Recent equipment developments have improved both the focus precision and the automation of 'shooting' the stack. A geared tripod head is both easier to use, and is more precise for aiming the camera assembly. For field use, a screw-type manual focusing rail permits accurate steps of about 250 µm. A motorized focusing rail, in conjunction the appropriate hardware and software can greatly simplify set-up, and can be completely automated for taking the images composing the stack. It is capable of step sizes as small as 2 µm. An ad-hoc Wi-Fi device allows smartphones, tablets, or computers, with the appropriate app, to control all functions of the camera and the focusing rail. The use of this equipment and computer innovations will be illustrated with photographs of weeds.

Fortifying Farms and Ranches Against Weed Invasion. Ralph E. Whitesides*[1], Earl Creech[1], Jay Davison[2]; [1]Utah State University, Logan, UT, [2]University of Nevada Cooperative Extension, Fallon, NV (130)

The traditional approach to weed management on most farms or ranches is similar to a person running on a treadmill. A treadmill allows a person to run or walk while staying in one place. As the exercise deck cycles around and around, the user exerts energy to maintain the set pace, but never really goes anywhere. Agricultural producers spend a great deal of resources (time and money) on what can be thought of as a weed management treadmill. The weed treadmill is always in motion. Treadmill speed is controlled by how well, or how poorly, the weeds were managed in the past. Regardless of speed, failure to keep pace in the annual battle with weeds immediately impacts profitability. The building blocks of successful weed management include prevention, mechanical/physical control, cultural control (including competitive crops and cropping practices), biological control, and chemical control. Although all of the building blocks of weed management are essential and important, weed prevention may be the most important. Weed prevention is an important part of protecting farms and ranches from invasive plants, and is a piece of a much larger picture. Successful weed management in the future will require more emphasis on prevention. Integrated pest management (IPM) is comprised of management strategies related to insects, diseases, and weeds. When the emphasis is primarily on weeds it is sometimes referred to as integrated weed management (IWM). Integrated weed management (IWM) is an effective balance of all tactics utilized to minimize the impact of weeds in all ecological situations. As components of IPM and IWM, prevention and preventive strategies are often overlooked or addressed only superficially. When prevention is utilized as part of IWM it is comprised of three lines of defense against the invasion of new weeds: prevent arrival, prevent establishment, and prevent spread. Depending on the weed species and its situation (present or not yet present on the farm), farmers and ranchers may focus their efforts on preventing arrival (arrival by water, wind, animals and humans, intentional introductions, contaminated agricultural and construction products, vehicles and equipment, and herbicide-resistant weeds), preventing establishment (by maintaining competitive stands, through scouting, and early detection and rapid response), and by preventing spread (using weed containment and management strategies). Whenever a new weed enters the biological system, it causes farm and ranch managers to spend more time and money on the weed management treadmill. No matter the initial cost, prevention is always the most economical approach to weed management.

Discussion – Herbicides and PPE: Label Requirements, Perceptions, and Reality.

DISCUSSION SESSIONS

Project 1 Discussion Session: Weeds of Range and Natural Areas

Moderator: James Leary, University of Hawaii, Kula, HI

Topic: *Weed Risk Assessment as a Decision-Making Tool for Invasive Species Management*

Pre-discussion information presented by James Leary

Definitions:

- A ***weed*** is a plant growing where it is not wanted by humans, but it is useful to qualify "not wanted" as meaning some effort is made by some party to remove the plant. (FAO 2005).
- As per Executive Order 13112 an "***invasive species***" is defined as a species that is: (i) non-native (or alien) to the ecosystem under consideration and (ii) whose introduction causes or is likely to cause economic or environmental harm or harm to human health.
- Weed Risk Assessment (WRA) was originally developed in the early 1990's in Australia and is defined as a science-based quarantine risk analysis tool for determining the weed potential of proposed new plant imports.
- The broad adoption of scientifically backed assessments rooted in ecological principles could add consistency across federal and state regulatory agencies, while preventing environmental degradation, alleviating economic losses, and helping to target critical management practices.

What is a weed risk assessment?

- A semi-quantitative analysis where botanists look up published and on-line information to answer 49 questions about a plant's biology, ecology & invasive tendencies elsewhere. The answers result in a score that predicts whether a plant is likely to be invasive (Pheloung 1995, Daehler et al. 2004).

Accuracy and consistency of A-WRA (Gordon et al. 2008, Daehler et al.2004):

- The accuracy of the Australian Weed Risk Assessment (WRA) in New Zealand, Hawaii, the Pacific Islands, Czech Republic, Bonin Islands and Florida correctly accepted or rejected over 80% of the time.
- In Hawaii, HPWRA has screened 1700 species and is 95% accurate in catching the would-be invasive plants and 85% accurate at identifying non-pests.
- Determined as the proportion of correct decisions, from data sets of known naturalized populations.
- It also commits relatively more false-positives (10% error rate) than false-negatives (1%), i.e.,risk averse.

Challenges and Limitations…Low Base Rates (Hulme 2012):

- Base rate is the success of a species from introduction to establishment, i.e., naturalization.

- Low base-rates of plant invasions limit the predictive power of weed risk assessment (Williamson 1996).
- The analyses of existing aliens form the foundation of current knowledge and ignores the multitude that have failed to naturalize, leading to base rate inflation.
- Only when knowledge of the introduction e□ort is taken into account can outlying families that exhibit higher naturalization rates be determined.

Challenges and Limitations continued…Impact:

- The proportion of naturalized species having known impacts may simply reflect the absence of evidence rather than evidence of absence regarding harmful e□ects. As a consequence, impacts have often been assumed to scale with the geographic distribution of a species (Parker et al. 1999).

Modified WRAs:

- HP-WRA – Hawaii Pacific WARA tailored to the ecoregion of the pacific basin
- US-WRA – A WRA developed for the entire US excluding geographic and climatic suitability due to large heterogeneity. It is more discriminate between major and non-invaders compared to A-WRA and with a lower sensitivity with no false positives/negatives, i.e., less risk averse.

Predicting Biofuel Invasiveness: A Relative Comparison to Crops and Weeds (Smith et al. 2015):

- Of the 40 species assessed, the A-WRA and US-WRA ranked 34 and 28 species, respectively, as high risk, including the major crops *alfalfa, rice, canola, and barley*.
- *cereal rye* received scores above (US-WRA) or comparable to (A-WRA) *kudzu*

Discussion

1. Are you familiar with the US-WRA or A-WRA?
    a. The U.S. model tries to include a level of uncertainty in the prediction. It provides a range around the prediction. It also includes zones where the species can be invasive. The model provides considerable improvement over the Australian model.
2. Is the US-WRA utilized in your area?
    a. In Hawaii, the Australian model type in being used.
    b. The process has been adopted by the ODA, the city of Portland, OR and the APHIS risk assessment on *Arundo*.
    c. In Montana, a citizen can petition to add a species to the noxious weed list.
    d. OR, WY, UT, HI, MT are states currently using WRAs.
    e. One of the challenges of using WRAs is a human bias: we assume that a given species cannot be a weed in some areas because it hasn't spread there yet. We would be well served to use a more conservative approach for listing an invasive species.

f. Exponential development of an invasion results in a slow recognition of a potential problem. Also, it takes time for a species to develop a mycorrhizal association that facilitates its subsequent invasion of an area.

3. What are some of the other industry pathways most likely to be impacted by the adoption of a WRA pre-entry import system?
   a. Biofuels
   b. Pharmaceuticals
   c. Carbon sequestering species
   d. Horticultural and ornamental species
   e. GMO's
   f. Crops selected for specific traits
   g. Aquarium trade; water gardening
   h. Transportation
   i. Industrial uses of plants (e.g., mining remediation)
   j. Online sales of plant species
   k. Global construction industries (moving of equipment worldwide); military equipment
   l. Mining rehabilitation often uses non-native species
   m. Governmental introductions (e.g., buffel grass as forage)
4. What is the current rate of deliberate new species introductions?
   a. In Idaho, about 6 species per year.
   b. We are whitelist country (any species can be brought in as long as it has not been banned); Australia is a blacklist country (every species introduction must be evaluated).
   c. 80% of the woody invasive species were brought in intentionally.
   d. Some species need human activities to facilitate their spread.
5. What is the economic value of new species introductions?
   a. Value of new species minus future management costs if it escapes.
   b. Oregon released a new economic impact study recently; usually there is only just a passing mention of what potential future management costs are likely to be for an invasive plant species.
   c. Oil and gas companies are often required to put up a bond in case there are cost overruns due to species escapes (such as for biofuels).
   d. State of Mississippi: need an escrow account for *Miscanthus* and eucalyptus species.
6. What are research areas that would improve the utility and adoption of a WRA?
   a. Native and invasive ranges of current plants: do we see changes occurring?
   b. Climate change: where species are likely to become a problem in the future? (e.g., species in Colorado are likely to become invasive in Montana in the future).
   c. In highly altered systems, how vulnerable are they to invasions when novel plant communities exist.

Nominations of a new Chair-Elect:

Jane Mangold nominated Shawna Bautista (19 votes). James Leary nominated John Madsen (5 votes). Shawna Bautista is the new Chair-Elect for the Range and Natural Areas Project of WSWS.

Chair 2016:
James Leary, University of Hawaii at Manoa, PO BOX 269, Kula, HI 96790
leary@hawaii.edu

Chair-Elect 2016:
Tim Harrington, United States Forest Service, PNW Research Station, 3625 93rd Ave SW, Olympia, WA 98512
tharrington@fs.fed.us

Chair-Elect 2017:
Shawna Bautista, United States Forest Service, PNW Region, 1220 SW 3rd Avenue, Portland, OR 97204

Attendees:

Name	Affiliation	Email address
Jane Mangold	Montana State University	jane.mangold@montana.edu
Kirk Howatt	North Dakota State University	kirk.howatt@ndsu.edu
Heather Olsen	Utah State University	heather.olsen@usu.edu
Emmett Phelan	Park County Weed & Pest, WY	emmett@parkcountyweeds.org
Jake Jarrett	Park County Weed & Pest, WY	jake@parkcountyweeds.org
Shawna Bautista	U.S. Forest Service	sbautista@fs.fed.us
Larry Lass	University of Idaho	llass@uidaho.edu
Dan Tekiela	University of Wyoming	drtekiela@gmail.com
Celestine Duncan	Weed Management Services	weeds1@mt.net
Rita Beard	Private	knapweed@gmail.com
Tom Whitson	University of Wyoming (retired)	tdwhitson@fritel.net
Rod Lym	North Dakota State University	rod.lym@ndsu.edu
Blake Thilmony	North Dakota State University	blake.m.thilmony@ndsu.edu
Corey Ransom	Utah State University	corey.ransom@usu.edu
Tom Getts	University of CA Coop. Ext.	tjgetts@ucanr.edu
Andy Currah	Sublette Co. Weed & Pest Dist.	andyscwp23@gmail.com
Clay Wood	University of Wyoming	cwood13@uwyo.edu
Beth Fowers	University of Wyoming	bfowers@uwyo.edu

Brian Mealor	University of Wyoming	bamealor@uwyo.edu
Chad Cummings	Dow AgroSciences	dccummings@dow.com
Vanelle Peterson	Dow AgroSciences	vfpeterson@dow.com
Richard D. Lee	USDI - BLM	richard_lee@blm.gov
Scott Nissen	Colorado State University	scott.nissen@colostate.edu
Jason Adams	North Dakota State University	jason.w.adams@ndsu.edu
Allen White	U.S. Forest Service	allenwhite@fs.fed.us
Harry Quicke	Bayer	harry.quicke@bayer.com
Tim Harrington	U.S. Forest Service	tharrington@fs.fed.us
John Madsen	USDA ARS	jmadsen@ucdavis.edu
Erik Lehnhoff	New Mexico State University	lehnhoff@nmsu.edu

Project 2 Discussion Section: Weeds of Horticultural Crops

Moderator: Dennis Tonks, ISK BioSciences, Kearney, MO

Topic: *Impact of Increased Irrigation Water Salinity on Crip Injury from Soil Residual Herbicides*

A business meeting was conducted at the beginning of the Horticulture section Discussion meeting. Andy Robinson was nominated as the new Chair Elect, no other nominations followed. The vote was unanimous in the affirmative.

A discussion followed about the impact of irrigation water salinity in crop injury from soil residual herbicides. Pamela Hutchinson provided some base material about herbicide behavior in saline conditions and soil chemical/structure changes that occur under highly saline conditions.

Discussion included injury to trees with several different residual herbicides that had not been previously seen before and speculation that salinity was the cause. Another comment was that some herbicides cause no injury under some soil types but do cause injury in calcareous soils.

Much of the discussion centered around the lack of general knowledge of how increasing salinity may affect crop growth with respect to herbicide injury.

Lynn Sosnoskie discussed a grant that was awarded to UC Davis to look at the effect of salinity on crop injury so more information will be available in the future.

Chair 2016:
Dennis Tonks, Isk Biosciences, 211 S. Platte Clay Way, Suite B Kearney MO 64060
tonksd@iskbc.com.

Chair Elect 2016:
Pam Hutchinson, Aberdeen Research & Extension Center, 1693 S 2700 W, Aberdeen, ID 83210.
phutch@uidaho.edu

Chair Elect 2017:
Andy Robinson, North Dakota State University/University of Minnesota, Loftsgard Hall, 4746, PO Box 6050, Fargo ND 58108
aprobins@umn.edu

Attendees:

Name	Organization	Email
Lynn Sosnoskie	UC Davis	lmsosnoskie@ucdavis.edu
Bill Cobb	Cobb Consulting	wtcobb43@gmail.com
Andy Robinson	NDSU/Univ of MN	aprobins@umn.edu

Caio Brunharo	UC Davis	cabrunharo@ucdavis.edu
Kai Uneda	Univ of AZ	kumeda@cars.arizona.edu
Jill Schroder	USDA-OPMP	jill.schroder@ars.usda.gov
Carly Libby	WSU	libbey@wsu.edu
Dennis Tonks	ISK Biosciences	tonksd@iskbc.com
Pamela Hutchinson	Univ of ID	phutch@uidaho.edu

Project 3 Discussion Section: Weeds of Agronomic Crops

Moderator: Steve Eskelsen, ADAMA USA, Kennewick, WA

Topic: *21st Century Technologies in Weed Management.*

Discussion was led by chair Steve Eskelsen on the topic of 21st Century Technologies for Weed Management. Technologies discussed included robotic weeders, aerial imagery, and use of unmanned aerial systems (UASs). On the topic of robotic weeders it was discussed as to whether this would be a viable option for non-high value crops. It was proposed that there needs to be greater interaction between weed scientists and ag engineers. For aerial imagery, discussion centered on needs of aerial imagery that could be used to identify weeds and to discriminate between crops and weeds to generate maps for precision application of herbicides to weeds. The use of UASs for application of herbicides to weed escapes was also discussed.

It was proposed that there should be a symposium involving ag engineers to discuss tools that are being developed for precision agriculture and how they can be used for weed control.

Discussion was called to a close and election of the new chair-elect for the Weeds of Agronomic Crops section of the Western Society of Weed Science was put up for vote. A call for nominations or volunteers was made. Chad Asmus volunteered for the position of chair-elect. A call for further nominations or volunteers was made. No other nominations or volunteers occurred. A vote was taken and was unanimous in favor of Chad Asmus for the position of Chair-elect. Meeting was adjourned.

Chair 2016:
Steve Eskelsen, ADAMA, 2915 Kent Brock Ct., Kennewick, WA 99338, 509-378-7349
steve.eskesen@us.adama.com

Chair-elect 2016:
Caleb Dalley, North Dakoda State University, PO Box 1377, Hettinger, ND 58639
caleb.dalley@ndsu.edu

Chair-elect 2017:
Chad Asmus, BASF Corporation, 2301 Bristol Lane, Newton, KS 67114
Chad.asmus@basf.com

Attendees:

Name	**Institution**	**Email**
Steve Eskelsen	ADAMA	steve.eskelsen@us.adama.com
Brian Jenks	NDSU	Brian.jenks@ndsu.edu
Brad Hanon	UC Davis	bhanson@ucfavis.edu
Marie Jasieniuk	UC Davis	mjasien@ucdavis.edu
Bill McCloskey	Univ of AZ	wmcclosk@email.arizona.edu
Ryan Rapp	Monsanto	Ryan.e.rapp@monsanto.com
Mayank Malik	Monsanto	Mayank.s.malik@monsanto.com
Mithila Jugulam	KSU	mithila@ksu.edu
Joel Felix	Oregon State Univ	Joel.felix@oregonstate.edu
Roger Gast	Dow AgroSciences	regast@dow.com
Prashant Jha	Montana State Univ	pjha@montana.edu
Alan Helm	Gowan Company	ahelm@gowanco.com
Edward Davis	Montana State Univ	edavis@montana.edu
Joe Yenish	Dow Agro Sciences	jpyenish@dow.com
Caleb Dalley	NDSU	Caleb.dalley@ndsu.edu
Roland Schirman	-	schirman@innw.net

Project 4 Discussion Section: Teaching and Technology Transfer

Moderator: Jenna Meeks, University of Wyoming, Lingle, WY

Topic: *Reaching Out: Who and How*

Discussion notes:

Discussion began with questions for Lynn Sosnoskie following her presentation regarding the "Twitterverse." Navigating and evaluating the social media realm is complicated. For example, just because people view a tweet, doesn't mean the response was positive. Therefore, the number of views is not a reliable measure of how people react to a post.

By posting on social media, it has been easier for citizens to "find an expert." The term of expert doesn't necessarily mean people are qualified to answer scientific questions which results in a potentially rapid spread of misinformation. With misinformation comes fear. The community attacking science relies on relating to people's emotions rather than sharing facts. As a scientist, it is important to know and share facts but to also appeal to people's humanity so they believe the facts presented.

The question was raised if there is a benefit for someone from industry to be on Twitter with all the negative connotations about companies. Again, the topic of marketing science and not emotion was discussed. There was a university study to determine words that matter and get people to pay attention. There is roughly 85% of the population who don't care about issues (GMO's, herbicides, food supply, etc.). The question then became if this population should be reached out and if taking a neutral rather than skewed approach is beneficial.

Interacting on social media is critical to "success." Rather than being a silent follower, interacting with other's posts and comments is how social media relationships are built. Without the interaction, it's hard to know if the thoughts regarding a post are positive or negative.

The discussion then changed to disseminating information through extension and how that has changed since social media and the internet. People learn things on twitter before extension professionals know the information. This has resulted in extension not being top-down anymore. Another question raised was is it now the responsibility of citizens to seek out information or is it extension's responsibility to reach out to all citizens? Without being in an academic setting, access to published articles is not readily available for free. The decision to publish in open access journals is becoming more popular along with providing raw data. While transparency is important, providing raw data to people who aren't trained to analyze data might manipulate data in a negative way.

Chair-elect:

Chair-elect is Dan Tekiela from University of Wyoming. Contact information pending. The incoming chair, Casey McKee of Anadarko, is unlikely to attend next year. Between Dan and myself we can chair the meeting in 2017.

<u>Chair 2016:</u>
Jenna Meeks, University of Wyoming, 1000 E. University Ave., Dept 3354, Laramie, WY 82071
Jmeeks8@uwyo.edu

<u>Chair-elect 2016:</u>
Casey McKee, Anadarko Petroleum Corp., 1368 S 1200 E Vernal, Utah 84078
casey.mckee@aggiemail.usu.edu

<u>Chair-elect 2017:</u>
Dan Tekiela, University of Wyoming, Department of Plant Sciences (Dept. 3354), 1000 E. University Ave., Laramie, WY 82071

Attendance:
Clarke Alder, Amalgamated Sugar Company
Carl Coburn, University of Wyoming
Brad Hanson, UC Davis
Albert Adjesiwor, University of Wyoming
Andy Robinson, North Dakota State University
Andrew Kniss, University of Wyoming
Jill Schroeder, US Department of Agriculture
Lynn Sosnoskie, UC Davis
Kai Umeda, University of Arizona
Breanne Tidemann, University of Alberta
Dalles Peterson, Kansas State University
Dave Johnson, DuPont
Brian Mealor, University of Wyoming
Bill Cobb, Cobb Consulting Service
Clint Beiermann, University of Wyoming
Clay Wood, University of Wyoming
Roswita Norris, UC Davis
Dan Tekiela, University of Wyoming
Kirk Howatt, North Dakota State University
Ryan Rapp, Monsanto
Daniel Adamson, University of Wyoming
Jane Mangold, Montana State University

Project 5 Discussion Session: Basic Biology and Ecology

Moderator: Todd Gaines, Colorado State University, Fort Collins, CO

Co-Chair: Brad Hanson, University of California, Davis, CA

Topic: *How can we harness genetic and physiological tools to advance understanding of weedy plants?*

1. The first item of business was to elect a co-chair for this session at the 2017 meeting. Nevin Lawrence from the University of Nebraska was nominated and elected to the position; he will co-chair the session in Coeur d'Alene, Idaho in 2017 and will chair in Anaheim, CA in 2018.

2. The initial discussion focused on the question of how weed scientists can harness new tools for studying genetics and physiology to better understand weeds, particularly as the cost of many of these techniques falls.

The question was posed as to whether we could put together a comprehensive enough research area and group to hold either a special symposia or possibly a coordinating committee to pursue outside multi-state funding for a basic biology/ecology weed project.

- One model for the coordinating committee idea was the WERA-77 and Jointed Goatgrass Initiative that came from that effort.
- The main topic ideas for this were:
    - Weed Seed Biology. Generally, a large scale effort to focus on factors controlling seed production, seed dormancy, seed banks, etc. and how we can put more effort into managing weeds during this phase of their lifecycle.
    - Weed Genetics. This idea was more along the lines of the discussion topic but was not discussed as deeply as the weed seed topic at this point in the session.
- Significant discussion was held on previous similar efforts;
    - The initial WERA-77 project (and JGG project) was funded by a federal line-item in the budget; has been less funding in recent iterations.
    - Comments were made that the original jointed goatgrass effort seemed to be more effective because off the focus on a single species across many states.
    - A newer multistate project focused on a suite of winter annual grass weeds has been more difficult to get traction on specific research projects.
    - The WERA-77 project have some funding for travel and coordination but not specific research funding that could be directed to the effort which has made it difficult to channel efforts.
    - However, it was noted that the writing process for the coordinating committee idea is not too difficult, just takes commitment. In the past, an experiment station director usually ends up holding these funds.

- Everyone agreed that a key to success would be to focus on leveraging additional monies for research, not just meeting coordination.
- A few specific ideas and comments discussed included:
    - Need to focus on something specific, rather than broad, to better define and coalesce research groups (and secure funding).
    - Maybe a single species again? Perhaps common lambsquarters?
    - Others saw strength in the seed/seedback idea. Capture basic biology funding around lifecycles, topics like dormancy, seed longevity in soil, what controls physiology of seed life/death. Seedbank under-studied and under-managed part of weed lifecycle. Newer research on RNA half-life in seeds – not clear what regulates that and whether it can be manipulated – maybe this is a new opportunity to use technology to study?
    - Other topics discussed included herbicide resistance and other stress adaptations.
        - Resistance is a fairly well-covered arena. But broader stress physiology, and non-target site resistance may play into large scale topics (eg weeds and climate change).

3. The next major discussion topic centered around genetic sequence resources for weed researchers. There are some whole and partial weed genomes available and in some cases transcriptomes. Is there a way to make these more available and easily shared (eg like the Arabidopsis project).
    - Comment that it would be difficult (and expensive) to curate and manage such a database. Also, the depth of knowledge on any given weed species would be fairly thin relative to the Arabidopsis or crop species projects. May not be worth it? Is this a legitimate use of resources (or even possible?).
4. Discussion about physiological tools that are available; both at the plant level and larger scale.
    - Comments on drought, stress, temperature. Can we use remote sensing, big data, high throughput phenotyping, weed sensing/mapping, precision management etc in new ways related to weeds? How are we measuring plant (ie weeds) parameters in a way to increase our knowledge of weeds and inform management decisions?
    - Comment that "Weed seed research can often be like soccer – it doesn't always take a lot of equipment. Pretty sophisticated information can be drawn from fairly simple experiments". (eg. ABA/GA regulation of downy brome seed).
5. Could we pull together a future symposia (WSSA or WSWS) on weed genetics?
    - Comments:
        - Interest in fitness traits (resistance and climate stress).

        - We sometimes don't even know basics (like ploidy) of our species of interest.
        - Can better understanding of weed genetics lead to better predictive value for weed invasion or adaptation?
        - Related to resistance, the copy number issue is really interesting. Given that other pests like insects commonly have multiple copies of genes that impart resistance. In hindsight we probably could have predicted the "new" resistance issues we see in weeds (eg multiple EPSPS copies in several species).

6. Can we work better with plant breeders to help bring weed competitive ability back to importance for cultivar development?
    - Comments on this topic area:
        - For 20 years breeders have said competitive ability is too quantitative to be part of the selection process
        - Trade offs – breeders breed for yield and disease resistance, hard to bring in weed competitive ability if it takes away from one of the primary goals.
            - What is a competitive trait? Most are probably multi-genic, although some environmental adaptive trait (drought, salt) would help with weed competition.
        - Some weed scientists said they are working with breeders to encourage breeding for competitive abilities. Public breeders after any edge in the market place.
        - We don't have the genetics for "yield" in most crops after decades and millions of dollars spent – hard to believe we could make much of a splash in determining the genetics of "competition".

7. How do we develop funding for basic biology and ecology weed research? How to get/keep this on Washington DC radar?
    - Comments on this topic area:
        - We are in danger of losing AFRI weeds program – only 35 proposals submitted last time. (20% success rate last time)
        - Some researchers felt the potential success was too low relative to the amount of effort invested – other, easier sources of funding.
        - We need to be persistent and resubmit proposals several years in a row.
        - Need better feedback from grant program managers. More transparency.
        - Reviewer change for every panel. Who is qualified to review weed genetics proposals but without conflict of interest? Can be difficult. May need more ad hoc reviewers.

- Need to remember that in many programs we're not just in competition with other weed scientists – all biologists.
- Look to the Joint Genome Initiative (JGI). Phytobiome project. How do we show the need for a similar weed genome project? This could be a way to strengthen sequencing and bioinformatics work in weeds.
- Maybe we need to explore more academia/industry collaborations. This would be along the lines of the SCRI model or the FFRI. Need to explore as researchers and as weed science organizations.

8. The discussion wrapped up with a recap of the meeting notes and corrections and additions to be added. Brad Hanson will chair the weed biology and ecology session in 2017 and Nevin Lawrence will co-chair (chair in 2018).

<u>Chair 2016:</u>
Todd Gaines, Colorado State University, Fort Collins CO 80523-1177
Todd.Gaines@colostate.edu

<u>Chair-elect (Co-chair) 2016:</u>
Brad Hansen, University of California, Davis, CA 95616
bhanson@ucdavis.edu

<u>Chair-elect 2017:</u>
Nevin Lawrence, University of Nebraska-Lincoln, Scottsbluff, NE 69361

<u>List of Attendees</u>

Neeta Soni	Colorado
Eric Patternson	Colorado
Curtis Hildebrandt	Colorado
Nevin Lawrence	Nebraska
Libby Karn	California
Marie Jasieniuk	California
Jane Mangold	Montana
Roland Shirman	Washington
Ian Burke	Washington
Rick Boydston	Washington
Abby Barker	Colorado
Robert Norris	California
Dean Pettinga	Colorado
Karl Ravet	Colorado

Jill Schroeder	Washington DC
Mithila Jugulam	Kansas
Tara Burke	Washington
Caio Brunharo	California
Shaheen Bibi	Colorado
Anita Kupper	Colorado
Brad Hanson	California
Joan Campbell	Idaho
Andrew Swain	Utah

Discussion Section: Education and Regulatory

Moderator: Sandra McDonald, Mountain West PEST, CO

Topic: *Herbicides and PPE: Label Requirements, Perceptions, and Reality.*

Carol Black of Washington State University Urban IPM & Pesticide Safety Education lead the WSWS Education and Regulatory Discussion with a presentation entitled "*Herbicides and PPE: Label Requirements, Perceptions, and Reality*." She presented information about personal protective equipment (PPE) that she has been working on nationally and internationally.

It became evident that pesticide label requirements for PPE were confusing at a NIOSH workshop on PPE in 2011. There was also an incorrect perception that many labels require spray suits.

Dr. Anugrah Shaw with the University of Maryland Eastern Shore surveyed existing labels to determine the range of PPE label requirements and the frequency of certain requirements found on labels. Based on these data she established baseline data on how often certain types of PPE are required on labels.

Carol shared Dr. Shaw's baseline data and a subset for herbicides during the Education and Regulatory Discussion. The data are from the labels in the Crop Data Management Systems (CDMS). A total of 1868 pesticide labels were analyzed and the product name, pesticide type (insecticide/herbicide/etc.), signal word, and PPE statements were tabulated; the herbicide subset includes 786 labels.

The Environmental Protection Agency (EPA) updated its Label Review Manual and label requirements in 2012 to make glove statements clearer. The eight glove types are ranked for their protection from solvent(s) in the formulation not the active ingredient.

The foundational research and report for current gloves statements stems from the work of Dr. A.D. Little in preparations for the Worker Protection Standards in the early 1990's. The study reported that generally the solvents within the formulation permeated the glove material first. The report summarized eight classes of solvents against eight glove types. The first category of solvent is water alone or a dry material. Many labels have not been updated since EPA's 2012 revised glove statements; thus, many labels reference the solvent categories as chemical resistant categories (i.e., category A, B, C, etc.), which is very confusing and often misquoted by registrants. The EPA Chemical Resistance Category Chart for Gloves is below ("for Gloves" was added in 2012). Note the glove thickness measured.

<u>Solvent Categories</u>

A = No solvent or aqueous solvent

Cat. B = Ketones

Cat. C = Alcohols

Cat. D = Acetates

Cat. E = Aliphatic petroleum distillates

Cat. F = Aromatic petroleum distillates < 40%

Cat. G = Aromatic petroleum distillates > 40%

Cat. H = Halogenated hydrocarbons

Solvent Category	Barrier Laminate	Butyl Rubber ≥ 14 mils	Nitrile Rubber ≥ 14 mils	Neoprene ≥ 14 mils	Natural Rubber ≥ 14 mils*	Poly-ethylene	Polyvinyl Chloride (PVC) ≥ 14 mils	Viton ≥ 14 mils
A (dry & water-based)	High	High	High	High	High	High	High	High
B	High	High	Slight	Slight	None	Slight	Slight	Slight
C	High	High	High	High	Moderate	Moderate	High	High
D	High	High	Moderate	Moderate	None	None	None	Slight
E	High	Slight	High	High	Slight	None	Moderate	High
F	High	High	High	Moderate	Slight	None	Slight	High
G	High	Slight	Slight	Slight	None	None	None	High
H	High	Slight	Slight	Slight	None	None	None	High

All glove statements found on labels today are based on the solvents that are in the formulation and in some situations the percentage of the solvent. A notation of "High" in the chart indicated protection by gloves worn all day and exposed to the concentrate for long periods of time.

Labels often do not state thickness, though the studies were based on 14 mil thickness for all but polyethylene gloves (food-handling gloves). However, a 2013 survey of applicators showed that 30% wore disposable gloves for dexterity and convenience. No studies have been published that document the protective level of disposable gloves.

Labels referring to chemical resistant and a category (A, B, C, etc.) are very confusing. Listing the specific, approved glove types provides for a clearer statement. Nitrile is commonly worn (63% disposable or reusable); however, they are not approved for categories B, G, or H – only barrier laminate (Silver Shield®) or Viton® gloves are allowed.

Of the 1868 pesticide labels tabulated:

- 140 had NO requirements for gloves!
- 2 labels, just said gloves
- 174 labels stated waterproof, but did not stipulate any particular glove type
- 1552 (83%) of the labels required "chemical resistant" gloves and 341 of these did not specify any category

Of the labels requiring chemical resistant gloves, 648 state "category A" meaning waterproof. Combine these with the labels that specify waterproof and most (822) of the product labels only require waterproof gloves. This number may actually be higher if the 341 labels that do not specify a category actually mean category A.

For our discussion, Carol showed the subset data for herbicides. Of the 786 herbicide labels tabulated:

- 2 labels, just said gloves
- 71 had NO requirements for gloves
- 47 labels stated waterproof
- 666 of the labels required chemical resistant gloves

Of the 666 herbicide labels requiring "chemical resistant" gloves:

- 343 stated waterproof (242 with various glove type combinations detailed)
- 126 allow for nitrile gloves, a common protective glove (categories C, E, F)
- 86 labels do not allow for nitrile gloves (categories B, F-or-G, G, G-or-H); only barrier laminate (Silver Shield®) or Viton®) allowed
- 111 did not specify a specific solvent category

Carol emphasized that it is important for everyone to carefully read and understand labels. If you need help with interpreting personal protective equipment statements, contact me, Carol Black (ramsay@wsu.edu) or the chemical company.

Respectfully submitted by:

Sandra McDonald (sandra@mountainwestpest.com)

2016 Education & Regulatory Section Chair

List of Attendees not available

WESTERN SOCIETY OF WEED SCIENCE NET WORTH REPORT

April 1, 2015 through March 31, 2016

ASSETS	
Cash and Bank Accounts	
American Heritage Checking	$80,212.17
American Heritage Money Market	$35,070.24
CD#1 1 yr @ 0.4%	$45,180.00
CD#2 2 yr @ 0.6%	$45,270.00
TOTAL Cash and Bank Accounts	$205,732.41
Other Assets	
Asset (Weeds of the West unsold inventory)	$25,407.45
TOTAL Other Assets	$25,407.45
Investments	
RBC Dain Rauscher Acnt	$196,267.45
TOTAL Investments	$196,267.45
TOTAL ASSETS	$427,407.31
OVERALL TOTAL	$427,407.31

WSWS CASH FLOW REPORT

April 1, 2015 through March 31, 2016

INFLOWS ($)	
Annual Meeting Income	75,615.00
Bio Control Of Invasives Book	82.35
California Weeds Books	45.00
Climex Workshop	245.00
Interest Inc	298.35
Renewal Membership	2,164.00
Royalty For Proceedings Or RPR	320.00
Student Travel Account	423.00
Sustaining Member Dues	13,500.00
Weed Control In Natural Areas	266.00
Weeds Of The West	34,765.63
TOTAL INFLOWS	127,724.33
OUTFLOWS ($)	
Annual Meeting Expense	38,072.90
Bank Charge	12.00
CAST Annual Dues	1,500.00
Director Of Science Policy	5,001.00
Insurance	500.00
Merchant Account	3,549.67
Misc	3.00
Misc Expense	500.00
Service Contract	25,000.00
Stipend	1,500.00
Supplies	302.23
Tax	226.00
Tax Preparation	458.73
Transfer	-
Travel To Summer Meeting	7,262.06
Travel To WSWS Meeting	659.80
Web Site Host	4,000.00
Weed Contest	3,868.08
TOTAL OUTFLOWS	92,415.47
OVERALL TOTAL	35,308.86

WSWS 2016 FELLOW AWARDS

Fellows of the Society are members who have given meritorious service in weed science, and who are elected by two-thirds majority of the Board of Directors.

Joe DiTomaso

Joe DiTomaso received his BS degree in Wildlife Biology in 1977 from the University of California, Davis, his MS degree in 1981 at Humboldt State University in Plant Taxonomy and his PhD in Weed Science at the University of California, Davis, in 1986. He was on the faculty at Cornell University from 1987 to 1994, where he primarily worked in the area of weed physiology. In 1995 he joined the University of California, Davis, Weed Science Program where he is a Cooperative Extension Weed Specialist and Professor. His research and extension program focuses on understanding the biology and ecology on invasive plants in natural areas and using this information to develop more effective, scientifically-based, and cost effect methods for their management. Over his career he has published over 140 peer-review manuscripts, authored 38 book chapters, and published four books, including *Weeds of the Northeast*, *Aquatic and Riparian Weeds of the West*, *Weeds of California and Other Western States*, and *Weed Control in Natural Areas in the Western United States*. He teaches two courses at UC Davis and has been the major advisor to 22 graduate students (10 PhD and 12 MS). Within his extension program, Joe has given over 850 presentations since 1995. Joe served as the President of three professional societies, including the Western Society of Weed Science (WSWS), California Invasive Plant Council (Cal-IPC), and the Weed Science Society of America (WSSA). He was the first editor of the new WSSA journal entitled *Invasive Plant Science and Management*, and served eight years in that capacity. He is the Director of the Weed Research and Information Center in the University of California, and served for eight years on the National Invasive Species Advisory Committee and five years on the California Invasive Species Advisory Committee. Among his awards, he received the Lifetime Achievement Award by Cal-IPC, Outstanding Weed Scientist Award by WSWS, and the Outstanding Extension Award by WSSA. He is also a Fellow of WSSA.

Jesse Richardson

Jesse Richardson has been an active member of WSWS since 1983. During those 32 years, he has been a consistent participant in the society in several roles – as oral paper presenter, WSWS officer, and committee member. As a WSWS officer, Jesse served as Secretary from 1992-1993 and as Research Section Chair from 1999-2000. He served as Program Chair in 2009 and President of the Society in 2010-2011. He has chaired six WSWS committees: Site Selection, Student Paper Contest, Program, Sustaining Membership, Poster, and Finance. Other committee assignments included Student Educational Enhancement and Herbicide Resistant Weeds. In 2006, he represented WSWS at a Shared Leadership Conference sponsored by CAST. He also served on the Local Arrangements Committee from 2012-2014 and served as chair. He is currently serving on the finance committee again serving as chair.

Jesse is a lifelong resident of the western U.S. Upon earning a Ph.D. in Agronomy/Weed Science at Washington State University, he began his career as a field Technical Service and Development Specialist for Dow Chemical in 1986. Having worked for the company for over 21 years, he is presently a Crop Protection R&D Specialist for Dow AgroSciences, working in agronomic and horticultural crops in California, Arizona, New Mexico and Texas. In addition to WSWS service, Jesse has provided leadership for the California Weed Science Society as Secretary, Vice President/Program Chair, President, and Past President. He considers his greatest accomplishment in life to be his F1 generation.

WSWS 2016 Honorary Member

This award was not conferred in 2016

WSWS 2016 OUTSTANDING WEED SCIENTIST – Prashant Jha

The Outstanding Weed Scientist, Early Career was awarded to Prashant Jha.

WSWS 2016 WEED MANAGER AWARD

This award was not conferred in 2016

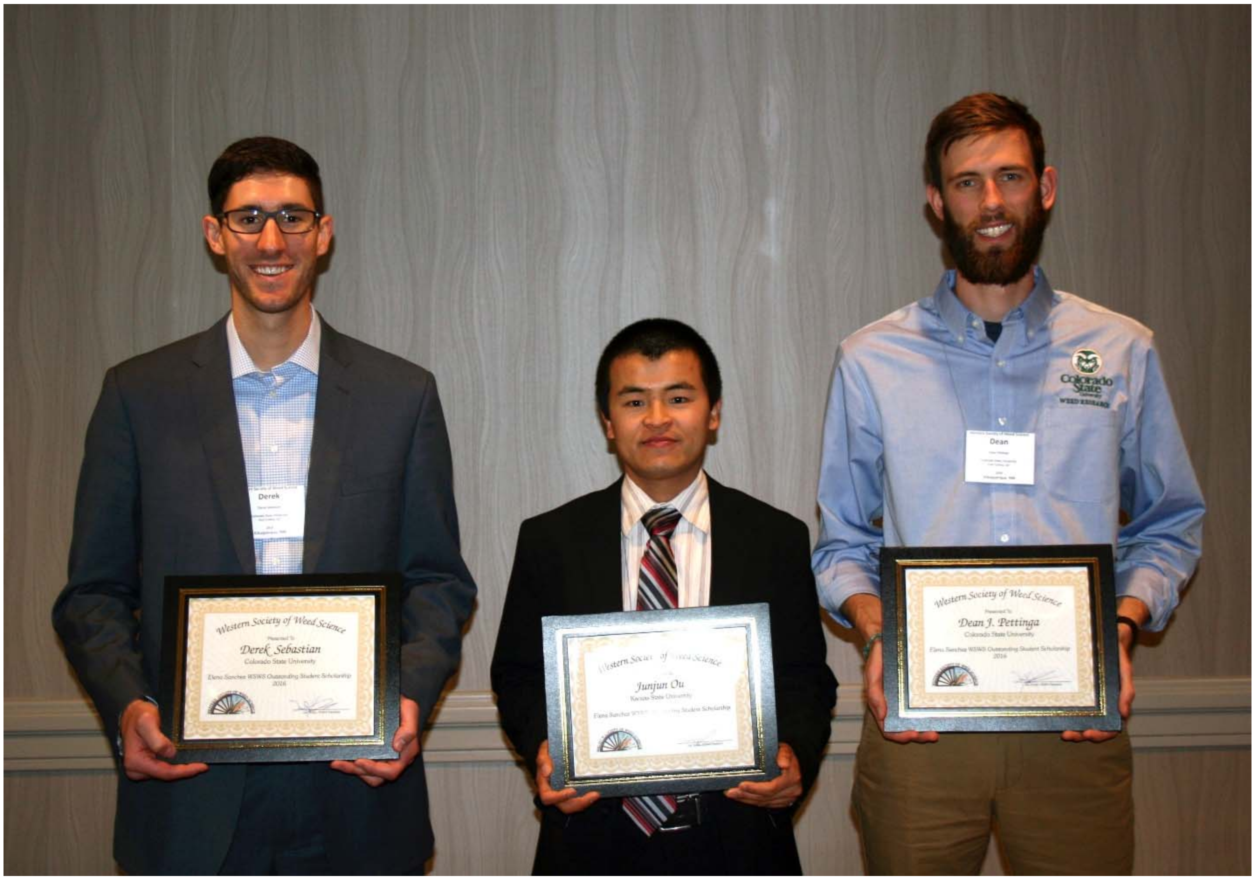
WSWS 2016 PROFESSIONAL STAFF AWARD

This award was not conferred in 2016

WSWS 2016 PRESIDENTIAL AWARD OF MERIT – Roland Schirman

Roland Schirman received the WSWS Presidential Award of Merit from Joe Yenish at the 2016 annual meeting in Albuquerque, New Mexico.

WSWS 2016 STUDENT SCHOLARSHIP RECIPIENTS



The awards committee received 9 applications for the Elena Sanchez Memorial Scholarship, all of which were outstanding in their own right. The quality of students in the field of weed science and the projects they are working on are impressive to say the least. This a direct reflection on the quality of scientists advising these students. Thank you for all of your hard work. With that said, the recipients of the Elena Sanchez Memorial Scholarship for 2016 are Derek Sebastian, Dean Pettinga, and Junjun Ou.

WSWS 2016 STUDENT PAPER AND POSTER AWARDS

The 2016 WSWS Student Paper Contest included 22 poster presentations and 25 oral presentations. All of the students who participated are to be commended for their excellent presentations. As has been done previously, the students with poster and oral presentations were each divided into two groups. According to the rules of the student paper contest, the number of winning places in the four groups varied from two to three, depending on the number of students in each group.

Oral Paper Contest Awards – Range and Natural Areas, Horticultral Crops and Teaching and Technology Transfer

First place winner was Derek Sebastian (middle), Colorado State University. His presentation was *Winter Annual Grass Control and Remnant Plant Community Response to Indaziflam and Imazapic*. Second place winner was Travis Carter (left), North Dakota State University and his presentation was *Prairie Response to Canada Thistle Infestation*. Winners pictured with WSWS President Joe Yenish.

Oral Paper Contest Awards – Agronomic Crops

First place winner was Junjun Ou (middle), Kansas State University and his paper was *Efficacy of Glyphosate and Dicamba Tank Mixes in Kochia*. Second place winner was Clint Beiermann (right), University of Wyoming and his presentations was *Effect of Winter Wheat Stubble Height on Dry Bean Growth and Development*. Third place winner was Curtis Hildebrandt (left), Colorado State University and his presentation was *Crop Safety Assessment of Mutagenesis-derived ACCase Resistant Wheat Lines*.

Oral Paper Contest Awards – Basic Biology and Ecology

First place winner was Breanne Tidemann (middle), University of Alberta and her presentation was *Potential Effects of Harvest Weed Seed Control on Wild Oat Populations Based on Demographic Modelling*. Second place winner was Carl Coburn (left), University of Wyoming and his presentation was *Experimental Methods for Confirming Resistance to Synthetic Auxin Herbicides*. Third place winner was Neeta Soni (right), Colorado State University and her presentation was *Determining Seed Retention of Key Annual Weeds at Wheat Harvest*.

Poster Presentation Awards – Range and Natural Areas, Horticultural Crops and Basic Biology and Ecology

First place was Carl Coburn (middle-left) from University of Wyoming. His winning poster was titled *Methods for Confirming Resistance to Different Herbicide Mode of Action: Does One Size Fit All?* Second place winner in the same group was Albert Adjesiwor (left), University of Wyoming. His poster was *Physiological Mechanisms of Shade Avoidance Response in Beta Vulgaris*. And third place was Samantha Willden (right), Utah State University. Her poster was *Phenology of the Biological Control Agent of Dalmation Toadflax in Utah*. Winners pictured with WSWS President Joe Yenish.

Poster Presentation Awards – Agronomic Crops

First place winner was Charlemagne Lim (left) from Montana State University and his poster was *Survival and Fecundity of Glyphosate-Resistant Kochia with Variable EPSPS Gene Copies in Response to Glyphosate Selection*. Second place winner was Rachel Zuger (middle), Washington State University and her poster was *An Overview of Herbicide-Resistant Weeds in Washington*. Winners pictured with WSWS President Joe Yenish.

Poster Presentation Awards – Undergraduate Posters

Undergraduate poster presentation winner was Jessica Bramhall (right), Kansas State University. Her winning poster was titled *Impact of Crop Competition on Fitness of Glyphosate-Resistant Kochia*. Winner pictured with WSWS President Joe Yenish.

WSWS 2016 ANNUAL MEETING NECROLOGY REPORT

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

Dr. Richard William Ward Baldwin,

Dr. Thomas Trost Bauman,

Dr. Wayne Stuart Belles,

Oliver George Russ, and

Dr. Stanford N. Fertig.

Individual obituraries were not available for the proceedings.

WSWS 2016 ANNUAL MEETING ATTENDEES – Albuquerque, New Mexico

Bruce Ackley
The Ohio State University
2021 Coffey Rd.
Columbus, OH 43210
ackley.19@osu.edu

Jason Adams
North Dakota State University
4415 CALICO DR S APT 110
Fargo, ND 58104
jason.w.adams@ndsu.edu

Daniel Adamson
University of Wyoming
1000 E University Ave.
Laramie, WY 82071
dadamso2@uwyo.edu

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

Joshua Adkins
Syngenta Crop Protection
4562 Barbera St
Richland, WA 99352
joshua.adkins@syngenta.com

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

Craig Alford
Dupont Crop Protection
8850 NW 62nd Ave
Johnston, IA 50131
craig.alford@dupont.com

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

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

Randy Anderson
Usda - Ars
2923 Medary Ave
Brookings, SD 57006
Randy.Anderson@ars.usda.gov

Samara Arthur
University of Idaho
3806 N 3600 E
Kimberly, Idaho 83341
samara@uidaho.edu

Chad Asmus
Basf Corporation
2301 Bristol Lane
Newton, KS 67114
chad.asmus@basf.com

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

Phil Banks
Marathon Agric & Environ Consulting
205 W Boutz Bldg 4 Ste 5
Las Cruces, NM 88005
marathonag@zianet.com

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

Judit Barroso
P.O. Box 370
Pendleton, OR 97801
judit.barroso@oregonstate.edu

Shawna Bautista
Us Forest Service
Po Box 3623
Portland, OR 97208
sbautista@fs.fed.us

Travis Bean
University of California, Riverside
Dept of Botany and Plant Sciences
Riverside, CA 92521
travis.bean@ucr.edu

Clint Beiermann
University of Wyoming
1000 E. University Ave.
Laramie, WY 82071
cbeierma@uwyo.edu

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

Pete Berrry
Oregon State University
1500 SW Jefferson St
Corvallis, Oregon 97331
berryp@oregonstate.edu

Brent Beutler
University Of Idaho
554 Hillcrest Avenue
American Falls, ID 83211
brent@libertyag.net

Shaheen bibi
Colorado State University
1177 Campus Delivery
Fort Collins, CO 80521
shaheen.bibi@colostate.edu

Carol Black
Washington State University
PO Box 646382
Pullman, WA 0
ramsay@wsu.edu

Aron Boettcher
Oregon State University / USDA
516 Southeast Hathaway Place
Corvallis, Oregon 97333
aron.a.boettcher@gmail.com

Rick Boydston
Usda-Ars
24106 N Bunn Road
Prosser, WA 99350
rick.boydston@ars.usda.gov

Jessica Bramhall
Kansas State University
1721 Claflin Road

Manhattan, KS 66506
bramhallja@ksu.edu

John Brock
Habitat Restoration & Invasiv Plt Mgmt
Po Box 25939
Tempe, AZ 85285
john.brock@asu.edu

Ian Burke
Washington State University
201 Johnson Hall
Pullman, WA 99164
icburke@wsu.edu

Joan Campbell
University Of Idaho
Pses Dept Box 442339
Moscow, ID 83844
jcampbel@uidaho.edu

Ken Carlson
DuPont Crop Protection
1109 NE 47th Street
Ankeny, Iowa 50021
kenneth.l.carlson@dupont.com

Travis Carter
North Dakota State University
1360 Albrecht Blvd
Fargo, ND 58102
travis.carter91@gmail.com

Leo Charvat
Basf Corporation
6211 Saddle Creek Trail
Lincoln, NE 68523
leo.charvat@basf.com

Dean Christie
Bayer Cropscience
4402 South Glendora Lane
Spokane, WA 99223
dean.christie@bayer.com

Chad Clark
Van Diest Supply Company
4419 Viewpoint Ct
FT COLLINS, CO 80526
chad.clark@vdsc.com

Pat Clay
Valent Usa Corporation
7498 N. Remmington Ave., Suite 102
Fresno, CA 93711
Pat.Clay@valent.com

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

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

Carl Coburn
University Of Wyoming
Dept 3354 1000 E University
Laramie, WY 82071
ccoburn2@uwyo.edu

Stephen Colbert
Dupont Crop Protection
1413 Sierra Drive
Escalon, CA 95320
stephen.f.colbert@dupont.com

Christiana Conser
UC Davis
One Shields Ave.
Davis, CA 95616
cconser@gmail.com

Scott Cook
Hubbard Ag Sciences
1320 N. Brookhaven Ln
Post Falls, ID 83854
scott@hubbardagscience.com

John Coyle
Colorado State University
1179 Campus Delivery
Fort Collins, CO 80523
jcoyle.02@gmail.com

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

Chad Cummings
Dow AgroSCiences
382 W. FM 1753
Bonham, TX 75418
dccummings@dow.com

Andy Currah
Sublette County Weed and Pest District
PO Box 729
Pinedale, Wyoming 82941
andyscwp23@gmail.com

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

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

Matthew Cutulle
Syngenta
7145 58th Avenue
Vero Beach, Florida 32967
matt.cutulle@syngenta.com

Greg Dahl
Winfield Solutions Llc
P. O. Box 83
River Falls, WI 54022
gkdahl@landolakes.com

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

Jim Daniel
Agra Syst
29391 CR 8
Keenesburg, CO 80643
Jimtdan@gmail.com

Johnson Dave
DuPont
701 56th ST.
Des Moines, IA 50312
david.hijohnson@dupont.com

Ed Davis
Montana State University
334 Johnson Hall
Bozeman, MT 59717
edavis@montana.edu

Franck Dayan
Colorado State University
1177 Campus Delivery

Fort Collins, CO 80523
franck.dayan@colostate.edu

Caio Augusto Brunharo
University of California, Davis
4400 Solano Park Circle, apt
1522
Davis, California 95616
cabrunharo@ucdavis.edu

Joe Ditomaso
University Of California - Davis
Dept Of Plant Sci, Mail Stop 4
Davis, CA 95616
jmditomaso@ucdavis.edu

Don Drader
Syngenta Crop Protection
7080 Dune Lake Rd Se
Moses Lake, WA 98837
donald.drader@syngenta.com

Celestine Duncan
Weed Management Services
Po Box 1385
Helena, MT 59624
weeds1@mt.net

Michael Dupre
Arysta Life Sciences
245 Freight Strreet
Waterbury, CT 6702
Michael.Dupre@arysta.com

Ryan Edwards
WinField Solutions
2777 Prairie Dr
River Falls, WI 54022
rjedwards@landolakes.com

Chad Effertz
Arysta Lifescience
4551 Hwy 41n
Velva, ND 58790
chad.effertz@arysta.com

Greg Endres
North Dakota State University
Res Ext Center Box 219
Carrington, ND 58421
gregory.endres@ndsu.edu

Steven Eskelsen
ADAMA
2915 Kentbrook Ct
Kennewick, WA 99338
bigesky@gmail.com

Erin Espeland
USDA ARS
1500 N. Central Ave
Sidney, MT 59270
erin.espelend@ars.usda.gov

Mirella Farinelli Ortiz
Colorado State University
Plant Sciences
Fort Collins, CO 80521
mirella.fortiz@gmail.com

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

Beau Ferguson
United Agronomy
317 1 Ave SE
Berthold, ND 58740
beau@unitedag.com

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

Gabriel Flick
Oregon State University
107 Crp Sciences Bldg.
Corvallis, OR 97331
gabriel.flick@oregonstate.edu

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

Beth Fowers
University of Wyoming
1000 E. University Ave
Laramie, WY 82071
bfowers@uwyo.edu

Kyle Frandsen
University of Idaho
3806 North 3600 East
Kimberly, Idaho 83341
kfrandsen@uidaho.edu

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

Angela Gadino
United Phosphorus Inc.
864 Sage Crest Dr.
Wenatchee, WA 98801
angela.gadino@uniphos.com

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

Mariano Galla
1 shields ave
Davis, California 95616
mfgalla@ucdavis.edu

Roger Gast
Dow Agrosciences
9330 Zionsville Rd
Indianapolis, IN 46268
regast@dow.com

Thomas Getts
University Of California
707 Nevada st.
Susanville, CA 96130
tjgetts@ucanr.edu

Greta Gramig
North Dakota State University
166 Loftsgard Hall, Ndsu
Fargo, ND 58102
greta.gramig@ndsu.edu

Brenda Grewell
USDA-ARS
Dept Plant Sci MS-4, 1 Shields
Ave
Davis, CA 95616
bjgrewell@ucdavis.edu

Kevin Gunnell
AgraServ Inc.
77 North 300 East
Mount Pleasant, UT 84647
klgunnell80@gmail.com

Jose Gutierrez
Nichino America
2257 S Miami Ave
Fresno, CA 93727
jgutierrez@nichino.net

Lloyd Haderlie
Agraserv Inc

2565 Freedom Lane
American Falls, ID 83211
lloyd@agraserv.com

Mustapha Haidar
American University Of Beirut
Bliss St, Aub, Fafs
Beirut, NY 10017
mhaidar@aub.edu.lb

Morgan Hanson
North Dakota State University
3202 N. Broadway Apt. 202
Fargo, ND 58102
morgan.d.hanson@ndsu.edu

Brad Hanson
University Of California - Davis
Ms-4; One Shields Ave
Davis, Ca 95616
Bhanson@ucdavis.edu

Dewayne Harper
Wilbur Ellis Company
8131 W Grandridge Blvd Suite 200
Kennewick, WA 99336
dharper@wilburellis.com

Timothy Harrington
Usda Forest Service
3625 93rd Ave Sw
Olympia, WA 98512
tharrington@fs.fed.us

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

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

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

Curtis Hildebrandt
Colorado State University
5381 North Highway 1
Fort Collins, CO 80524
cuhilde@rams.colostate.edu

Barbara Hinds-Cook
Oregon State University
107 Crop Science Bldg
Corvallis, OR 97331
Barbara.Hinds-Cook@oregonstate.edu

Samantha Hogstad
North Dakota State University
Dept of Plant Sciences P.O. Box 6050
Fargo, ND 58108
Samantha.Hogstad@ndsu.edu

Harvey Holt
Green Systems Analytics, Llc
10203 47th Avenue Sw, B-9
Seattle, WA 98146
holth@purdue.edu

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

Kirk Howatt
North Dakota State University
Ndsu Dept 7670 Po Box 6050
Fargo, ND 58108
kirk.howatt@ndsu.edu

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

Pam Hutchinson
Univ Of Idaho Aberdeen R & E Center
1693 S. 2700 W.
Aberdeen, ID 83210
phutch@uidaho.edu

Daigo Itaya
Kumiai
11 Martine Avenue Suite 1460
White Plains, NY 10606
itaya@kichem-usa.com

James Jackson
Texas A&M Agrilife
1229 U.S. Hwy 281 N
Stephenville, Texas 76401
Jamesr.jackson@ag.tamu.edu

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

Marie Jasieniuk
University Of California
Dept Plant Sciences Ms 4
Davis, CA 95616
mjasien@ucdavis.edu

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

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

Prashant Jha
Montana State University - Bozeman
SO Ag Res. Center 748 Railroad Hwy
Huntley, MT 59037
pjha@montana.edu

Everitt John
Monsanto
10007 N. CR. 1300
Shallowater, TX 79363
john.d.everitt@monsanto.com

Marshall Jonathon
PO Box 269
Kula, HI 96700
jdkmarsh@hawaii.edu

Mithila Jugulam
2004 Throckmorton, Department of Agronomy
Manhattan, KS 66506
mithila@ksu.edu

Elizabeth Karn
UC-Davis
One Shields Ave
Davis, CA 95616
evkarn@ucdavis.edu

Blake Kerbs
Oregon State University

2515 NW Fairlawn ST
Corvallis, Oregon 97330
kerbsb@onid.oregonstate.edu

Robert Klein
University Of Nebraska
402 West State Farm Road
North Platte, NE 69101
rklein1@unl.edu

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

Jeffrey Krumm
DuPont Crop Protection
2815 S. Ridge Road
Hastings, NE 68901
jeffrey.t.krumm@dupont.com

Anita Kuepper
Colorado State University
C129C Plt Sci. Bldg 1177
Campus Del.
Fort Collins, Colorado 80523
akuepper@rams.colostate.edu

Vipan Kumar
Montana State University
748 Railroad Hwy
Huntley, MT 59037
vipan.kumar@montana.edu

Christopher Landau
NMSU
EPPWS, Skeen Hall
Las Cruces, NM 88005
clandau@nmsu.edu

Thomas Larsen
10748 S Autumn Wind Way
South Jordan, Utah 84009
toml@amvac-chemical.com

Larry Lass
University Of Idaho - Pses Dept
875 Perimeter Drive #2339
Moscow, ID 83844
llass@uidaho.edu

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

James Leary
University Of Hawaii At Manoa
Po Box 269
Kula, HI 96790
leary@hawaii.edu

Codee Lee
North Dakota State University
1318 12th St. N
Fargo, ND 58102
codee.z.lee@ndsu.edu

Richard Lee
Bureau of Land Management
Denver Federal Center, Bldg 50
Denver, CO 80225
richard_lee@blm.gov

Erik Lehnhoff
New Mexico State University
EPPWS, Skeen Hall
Las Cruces, NM 88001
erik.lehnhoff@montana.edu

Carl Libbey
Washington State University
16650 Sr 536
Mt Vernon, WA 98273
libbey@wsu.edu

Charlemagne Alexander Lim
748 Railroad Highway
Huntley, Montana 59037
charlemagnealexa.lim@msu.montana.edu

Mingyang Liu
Oregon State Univ.
109 Crop Sciences Bldg.
Corvallis, OR 97331
mingyang.liu@oregonstate.edu

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

Rod Lym
North Dakota State University
Dept 7670 Po Box 6050
Fargo, ND 58108
rod.lym@ndsu.edu

Drew Lyon
Washington State University
Po Box 646420
Pullman, WA 99164
drew.lyon@wsu.edu

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

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

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

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

Bill McCloskey
University Of Arizona
Plant Sci - Forbes 303; Po Box 210036
Tucson, AZ 85721
wmcclosk@email.arizona.edu

Kirk Mcdaniel
New Mexico State University
1818 s. fairacres rd
las cruces, nm 88005
kmcdanie@nmsu.edu

Sandra Mcdonald
Mountain West Pest
2960 Southmoor Drive
Ft Collins, CO 80525
sandra@mountainwestpest.com

Brian Mealor
University Of Wyoming
3401 Coffeen Ave
Sheridan, WY 82801
bamealor@uwyo.edu

Case Medlin
Bayer
101 Crossroad Ct.
Paradise, TX 76073
case.medlin@bayer.com

Jenna Meeks
University of Wyoming
Dept. 3354 1000 E University Ave
Laramie, WY 82071
jmeeks8@uwyo.edu

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

Fabian Menalled
Montana State University
719 Leon Johnson Hall
Bozeman, MT 59717
menalled@montana.edu

Abdel Mesbah
New Mexico State University
136 Garret Rd
Clovis, NM 88101
aomesbah@nmsu.edu

Thomas Mesman
3719 Player Pl
Clovis, NM 88101
tmesman9@nmsu.edu

Hubbard Michael
Hubbard Ag Science
4181 District Five Road
Bonners Ferry, ID 83805
Mike@hubbardagscience.com

Tim Miller
Washington State Univ - Mt Vernon
16650 State Route 536
Mt Vernon, WA 98273
twmiller@wsu.edu

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

Edward Morris
New Mexico State University
P.O. Box 30003, Msc 3be
Las Cruces, NM 8803
edmorris@nmsu.edu

Leeland Murray
New Mexico State University
EPPWS Skeen Hall Room N140
Las Cruces, NM 88003
leeland9@nmsu.edu

Todd Neel
Usda Forest Service
200 E. Broadway
Missoula, MT 59802
toddaneel@fs.fed.us

Karnes Neill
WinField
714 W. Evelyn St
Lewistown, MT 59457
KENeill@landolakes.com

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

Robert Norris
University Of California
25112 Central Way
Davis, CA 95616
rfnorris@ucdavis.edu

Heather Olsen
Utah State University
4820 Old Main Hill
Logan, Utah 0
heather.olsen@usu.edu

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

Michael Ott
Terra Biologics
1005 N Warson Rd Suite 401
St Louis, MO 63132
ott@niduspartners.com

Junjun Ou
2004 TH
MANHATTAN, Kansas 66506
junjun@ksu.edu

Eric Patterson
Colorado State University
1177 Campus Delivery
Fort Collins, Colorado 80523
lloyd16@rams.colostate.edu

Melman Paul
Colorado State University
1472 Campus Delivery
Ft. Collins, CO 80523
paul.melman@colostate.edy

Vanelle Peterson
Dow Agrosciences
P.O. Box 271849
Fort Collins, CO 80527
vfpeterson@dow.com

Ryan Peterson
Vision Research Park
317 1st Avenue Se
Berthold, ND 58718
peterson@visionresearchpark.com

Dallas Peterson
Kansas State University
2014 Throckmorton Hall
Manhattan, KS 66506
dpeterso@ksu.edu

Dean Pettinga
Colorado State University
1177 Campus Delivery
Fort Collins, Colorado 80521
deanpett@gmail.com

Emmett Phelan
Park County Weed & Pest Ctrl District
1067 Road 13
Powell, WY 82435
emmett@parkcountyweeds.org

Ray Pigati
Winfield
1050 County Rd. F West
Shoreview, MN 55126
rlpigati@landolakes.com

Patti Prasifka
Dow Agrosciences
3611 12th Street West
West Fargo, ND 58078
plprasifka@dow.com

Wiharti Purba
Washington State University
16650 SR 536
Mount Vernon, Washington 98273
wiharti.purba@wsu.edu

Steve Pyle
Syngenta Crop Protection
410 Swing Road

Greensboro, NC 27455
steve.pyle@syngenta.com

Harold Quicke
Bayer
1140 Shoreline Dr.
Windsor, CO 80550
harry.quicke@bayer.com

Adrian Quicke
Colorado State University
1177 Campus Delivery
Fort Collins, CO 80521
agquicke@gmail.com

Alan Raeder
Washington State University
Po Box 1389
Pullman, WA 99163
araeder@wsu.edu

Curtis Rainbolt
Basf Corporation
4123 N Annata Ave
Meridian, ID 83646
curtis.rainbolt@basf.com

Merchant Rand
BASF
6660 Delmonico Dr. Box 34 St. D
Colorado Springs, CO 80919
rand.merchant@BASF.com

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

Ryan Rapp
Monsanto Company
40660 252nd St
Mitchell, SD 57301
ryan.e.rapp@monsanto.com

Traci Rauch
University Of Idaho/Pses Dept
875 Perimeter Drive Ms 2339
Moscow, ID 83844
trauch@uidaho.edu

Karl Ravet
Colorado State University-BSPM Dpt
307, University Ave.
Fort Collins, Colorado 80523
karl.ravet@colostate.edu

Ryan Rector
Monsanto Company
800 N Lindbergh Blvd
St. Louis, MO 63167
ryan.j.rector@monsanto.com

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

Chuck Rice
Basf Corporation
725 N Center Pkwy #R302
Kennewick, WA 99336
chuck.rice@basf.com

Jesse Richardson
Dow Agrosciences
9846 Lincoln Ave
Hesperia, CA 92345
jmrichardson@dow.com

Beard Rita
Invasive Species Specialist
1912 Pawnee Dr.
Ft. Collins, CO 80525
rknapweed@gmail.com

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

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

Kirk Sager
Fmc Corporation
5431 Rd 11.7 Nw
Ephrata, WA 98823
kirk.sager@fmc.com

Gustavo Sbatella
University Of Wyoming
747 Road 9
Powell, WY 82435
gustavo@uwyo.edu

Roland Schirman
Washington State University - Retired
Po Box 181
Dayton, WA 99328
schirman@innw.net

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

Jill Schroeder
Usda Office Of Pest Mgmt Policy
1400 Independence Ave., Sw
Washington, DC 20250
jill.schroeder@ars.usda.gov

Kara Schut
Wilbur-Ellis
8106 Ingalls Road
Belding, Michigan 48809
kschut@wilburellis.com

Brian Schutte
New Mexico State University
945 College Avenue
Las Cruces, NM 88012
bschutte@nmsu.edu

Parrish Scott
Agrasyst
16417 NORTH NAPA
SPOKANE, WA 99206
scott.parrish@agrasyst.com

Derek Sebastian
1179 campus delivery Weed lab 114
Fort Collins, CO 80523
derek.sebastian@rams.colostate.edu

Tye Shauck
3907 W 20th Ave
Kennewick, WA 99338
tye.shauck@basf.com

Wes Smalling
Fremont County Weed & Pest
450 N. 2nd St.
Lander, WY 82520
wsmalling@wyoming.com

Randy Smith
Dow AgroSciences
14813 Bixby Drive
Westfield, IN 46074
rsmith4@dow.com

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

Lynn Sosnoskie
University Of California - Davis
Dept Of Plant Sciences, Uc
Davis
Davis, CA 95616
lynn.sosnoskie@gmail.com

David Spak
Bayer
2 TW Alexander Drive
RTP, NC 27527
david.spak@bayer.com

Phil Stahlman
Kansas State University
1232 240th Avenue
Hays, KS 67601
stahlman@ksu.edu

James Stapleton
University of California
9240 S. Riverbend Avenue
Parlier, CA 93648
jjstapleton@ucanr.edu

Orloff Steve
University of California
1655 S Main St
Yreka, CA 96097
sborloff@ucdavis.edu

Scott Swain
Utah State University
4820 Old Main Hill
Logan, UT 0
s.andrew.swain6@gmail.com

Burke Tara
Washington State University
2602 Pullman Albion Rd. Space
B1
Pullman, WA 99163
tara.leigh.burke@gmail.com

Nicole Tautges
Washington State University
Johnson Hall Room 201
Pullman, WA 99164
nicole.tautges@wsu.edu

Daniel Tekiela
University of Wyoming
1000 E University Ave
Laramie, WY 82071
tekiela2@vt.edu

Blake Thilmony
North Dakota State University
1360 Albrecht Boulevard
Fargo, ND 58102
blake.m.thilmony@ndsu.edu

Curtis Thompson
Kansas State University
2014 Throckmorton Hall
Manhattan, KS 66506
cthompso@ksu.edu

Michael Thornton
University of Idaho
3806 N 3600 E
Kimberly, Idaho 83341
mthornton@uidaho.edu

Breanne Tidemann
University of Alberta
116St and 85 Ave.
Edmonton, Alberta T6G 2R3
blaturnu@ualberta.ca

Olivia Todd
Colorado State University
1177 campus delivery
Fort Collins, Colorado 80521
oetodd@gmail.com

Dennis Tonks
Isk Biosciences
211 S. Platte Clay Way Suite B
Kearney, MO 64060
tonksd@iskbc.com

Stu Turner
Turner & Co. Inc.
5903 Kilawea Drive
West Richland, WA 99353
agforensic@aol.com

Gary Tuxhorn
United Suppliers Inc
13215 Forest Oaks Drive
Smithville, MO 64089
garytuxhorn@gmail.com

Kai Umeda
University Of Arizona
4341 East Broadway
Phoenix, AZ 85040
kumeda@cals.arizona.edu

Jared Unverzagt
3772 Potosi Street
Bozeman, MT 59718
jared.unverzagt@basf.com

Stephen Valenti
Monsanto Company
5132 Rosecreek Pkwy
Fargo, ND 58104
stephen.a.valenti@monsanto.co
m

Lee Van Wychen
Wssa-Director Of Science Policy
5720 Glenmullen Pl
Alexandria, VA 22303
Lee.VanWychen@wssa.net

Jim Vandecoevering
Basf Corporation
104 E Fairview Ave #226
Meridian, ID 83642
jim.vandecoevering@basf.com

Dave Vos
South Dakota State University
235 Berg Ag Hall
Brookings, SD 57007
dave.vos@sdstate.edu

Nami Wada
Oregon State University
3050 SW Campus way,
Corvallis, Oregon 97330
nami.wada@oregonstate.edu

Jacob Watt
Hubbard Ag Scince
313 E Thorn Street
Colfax, WA 99111
jake.watt@hubbardagscience.co
m

Phil Westra
Colorado State University
112 Weed Lab
Ft Collins, CO 80523
cows19@comcast.net

Allen White
Usda Forest Service
333 Broadway Blvd Se
Albuquerque, NM 87102
allenwhite@fs.fed.us

Ralph Whitesides
Utah State University

4820 Old Main Hill
Logan, UT 84322
ralph.whitesides@usu.edu

Tom Whitson
University Of Wyoming
80 Mejor Lado
Santa Fe, NM 87508
tdwhitson@tritel.net

Samantha Willden
Utah State University
Logan, UT 84322
Logan, Utah 84321
samwillden@gmail.com

Mike Wille
Fremont County Weed & Pest
Ctrl Dist
2229 West Bend Ave
Riverton, WY 82501
mwille@wyoming.com

Devin Wirth
North Dakota State University
166 Loftsgard Hall
Fargo, ND 58102
devin.a.wirth@ndsu.edu

Clay Wood
University of Wyoming
1000 E University Ave
Laramie, Wyoming (WY) 82071
clay.w.wood@gmail.com

Mark Wrucke
Bayer Cropscience
19561 Exceptional Trail
Farmington, MN 55024
mark.wrucke@bayer.com

Joe Yenish
Dow Agrosciences
1001 Calendula Circle
Billings, MT 59105
jpyenish@dow.com

Kert Young
New Mexico State University
PO Box 30003; MSC 3AE
Las Cruces, NM 88003
kry@nmsu.edu

Bob Zimdahl
Colorado State University
1010 East County Rd. 68
Ft. Collins, CO 80524
R.Zimdahl@colostate.edu

Rich Zollinger
North Dakota State University
Dept Of Plant Sci 7670
Fargo, ND 58108
r.zollinger@ndsu.edu

Rachel Zuger
Washington State University
Johnson Hall Room 164
Pullman, WA 99164
rachel.zuger@wsu.edu

WSWS 2016 ANNUAL MEETING – AUTHOR INDEX

Index of authors and their abstract numbers.

Ackley, Bruce A.	56, 57
Adams, Jason W.	94
Adams, Jason W.	115
Adamson, Daniel	46
Adjesiwor, Albert T.	60, 141
Al-Khatib, Kassim	29
Alexander, Brendan	142
Alston, Diane	73
Anderson, Monte D.	42, 90
Angadi, Sangu	51
Argueso, Juan L.	2
Arino, Gigi	36
Arthur, Samara L.	23, 53, 79
Asolkar, Ratnakar	139
Backscheider, Kelly A.	41
Bailey, Derek	14
Barker, Abigail	2
Barnhill, James	6
Barroso, Judit	38, 43
Bautista, Shawna L.	104
Beckett, Tom H.	76
Beiermann, Clint W.	112

Berry, Pete A.	50
Berry, Richard J.	66
Beutler, Brent	75
Bibi, Shaheen	52, 153
Bluemer, Brad	106
Bobadilla, Lucas K.	31
Boddy, Louis	139
Boettcher, Aron A.	38, 43
Borrelli, Kristy	82
Boydston, Rick A.	37, 45
Bramhall, Jessica A.	1
Brock, John H.	99
Brock, Kelsey	8
Brunharo, Caio	30
Bugg, Jessica R.	41
Burayu, Worku	24
Burke, Ian C.	15, 37, 45, 63, 82, 132, 146
Burke, Tara	15
Campbell, Joan	42
Carbonari, Caio A.	139
Carlson, Kenneth L.	40, 81
Carpenter, Jeff	137
Carr, Patrick	21, 22
Carter, Travis R.	13
Carter, Travis R.	105

Castner, Eric P.	41, 81, 136
Che, Jerry	24
Claypool, David A.	62, 112
Cobb, William T.	92, 93
Coburn, Carl W.	65, 120
Cook, Gil	132
Coyle, John B.	107
Crawford, Terry	70
Creech, Cody F.	134
Creech, Earl	130
Currie, Randall S.	154
Curtis, Daniel W.	83, 84, 157
Cutulle, Matt A.	36
D'Amato, Anthony W.	101
Dadjouy, Saleh	123
Dahl, Greg K.	111, 133
Daniel, Jim T.	59
Davison, Jay	130
Dayan, Franck	2, 119
Dayan, Franck E.	139
de Figueiredo, Marcelo	34
Diedrick, Keith A.	40
Dille, J Anita	1, 153
Duncan, Celestine	126
Dunne, Cheryl L.	36, 76

Edmund, Richard M.	41
Edwards, Michael T.	41
Edwards, Ryan J.	111, 133
Endres, Gregory J.	58, 155
Espeland, Erin K.	10
Evans, Edward W.	20
Felix, Joel	35, 74
Flanagan, Helen	137
Flick, Gabriel D.	80
Forbert, Michael	9
Forster, Peter C.	110
Fowers, Beth	96, 149
Frandsen, Kyle	23, 53, 79
Friebe, Bernd	117
Fuerst, E. Patrick	82
Futrell, Caryn J.	9
Gaines, Todd	2, 3, 34, 52, 85, 116, 119, 122, 152
Gaines, Todd A.	4, 121, 140, 153
Galla, Mariano F.	29
Gast, Roger	88, 109
Gednalske, Joe V.	133
Geier, Pat	154
Getsinger, Kurt D.	106
Giacomini, Darci	153
Gill, Bikram S.	117

Gillilan, JoAnna A.	133
Gomes, Giovanna L.	139
Gooding, Jeremy	7, 102
Gramig, Greta G.	21, 22
Grewell, Brenda J.	9
Haidar, Mustapha A.	47
Haley, Scott	85, 152
Hall, Linda M.	142
Hanson, Brad	32, 156
Hanson, Bradley D.	27, 29, 30, 31, 145
Hanson, Morgan D.	92
Harker, K. Neil	142
Harrington, Timothy B.	101
Hatler, William L.	40
Hauvermale, Amber	37
Hauvermale, Amber L.	63, 146
Hicks, Charles T.	16
Hildebrandt, Curtis M.	85
Hinds-Cook, Barbara J.	39
Hogstad, Samantha K.	22
Howatt, Kirk A.	59, 67, 89, 92
Hulting, Andrew	54, 157
Hulting, Andrew G.	39, 50, 83, 84, 87
Hutchinson, Pamela	75
Ishida, Joey	74

J, Anjani	35
J, Anjani	33, 61, 64, 108
Jain, Rakesh	36
Jasieniuk, Marie	118
Javier, Cleve	8
Jenkins, Daniel	103
Jenks, Brian M.	86, 155
Jester, Jennifer	151
Jha, Prashant	33, 35, 61, 64, 108
Johnson, David H.	41, 136, 137
Johnson, Keith D.	40, 81, 136
Jugulam, Mithila	1, 117, 135, 153
Karn, Elizabeth	118
Kerbs, Blake D.	87
Kessler, Kallie C.	34
Kilian, Robert	10
Kleczewski, Victoria A.	41
Klein, Robert N.	91
Kniss, Andrew R.	46, 60, 62, 65, 95, 112, 120, 138, 141
Koo, Dal-Hoe	117
Koppel, Amanda L.	40
Kruger, Greg R.	34
Krumm, Jeffrey T.	40, 41, 81, 136
Kuepper, Anita	34, 152
Kumar, Vipan	35, 61

Kumar, Vipan	33, 64, 108
Landau, Christopher A.	51
Larry, Hageman H.	41
Lass, Larry W.	12
Lawrence, Nevin C.	37, 63, 146
Leary, James	103
Leary, James K.	7, 102
Lee, Brian P.	138
Lee, Bumkyu	144
Lee, Codee Z.	89
Lee, Kijong	144
Lehnhoff, Erik A.	143
Leland, Shane	64, 108
Leland, Shane	33, 61
Libbey, Carl R.	25
Lim, Charlemagne A.	33
Lim, Charlemagne A.	61, 64, 108
Liu, Mingyang	54, 87
Long, Dan	38, 43
Lorent, Louise	37
Lorent, Louise	132, 146
Lucey, Bill	8
Lym, Rodney G.	11, 13, 105, 125, 126, 127
Lyon, Drew	15, 37
Madsen, John D.	106

Mallory-Smith, Carol	39, 50, 54, 80, 83, 84, 87, 157
Mallory-Smith, Carol	144
Manmathan, Harish	152
Mann, Rick K.	78
Marshall, Jonathan D.	7
McCloskey, William	131, 152
McDaniel, Kirk	14, 98
McKay, Alistair H.	78
Mealor, Brian A.	17, 95, 96, 138, 147, 148, 149
Meeks, Jenna	138
Meiman, Paul	107
Mesbah, Abdel	51
Mesman, Taylor	49
Miller, Timothy W.	25, 100
Mitchell, Steven	137
Miura, Tomoaki	7
Moechnig, Michael	88, 109
Moretti, Marcelo L.	31
Morishita, Don	23, 35, 53
Morishita, Don W.	79, 114
Morran, Sarah	32
Morris, Edward	28, 49
Mueller, James P.	78
Muscha, Jennifer	10
Nischwitz, Claudia	73

Nissen, Scott J.	16, 34, 107, 116, 126, 140, 150, 152
Norris, Robert F.	129
O'Connell, Mary A.	71
Olsen, Heather E.	5, 6, 124
Orloff, Steve B.	19, 156
Ostlie, Mike H.	155
Ou, Junjun	135
Owens, Daniel K.	139
Paisley, Steve I.	138
Parrish, Scott	59
Patterson, Eric	4, 152
Patterson, Eric L.	116, 121
Peter, David H.	101
Petersen, Mark	10
Peterson, Dallas E.	117
Peterson, Vanelle F.	126
Pettinga, Dean	122, 153
Pigati, Raymond L.	111, 133
Polziehn, Kristina	142
Porter, Donald J.	36, 110
Prasifka, Patricia	88, 109
Prather, Timothy	12
Preston, Christopher	34
Putta, Karthik	117
Quicke, Adrian	4, 153

Raeder, Alan J.	15, 132
Ransom, Corey	5, 6, 18
Ransom, Corey V.	73, 124
Rauch, Traci	42
Ravet, Karl	153
Ravet, Karl	4, 52, 121
Rew, Lisa	143
Richardson, Jesse M.	78
Robinson, Andy	26
Rodriguez, Jeanette A.	37, 146
Rodriguez, Roberto	103
Roerig, Kyle	83, 84, 157
Roerig, Kyle C.	39, 50
Rupp, Robert N.	40, 41, 81, 136
Saini, Monika	110
Saunders, David W.	81
Sbatella, Gustavo M.	46, 48, 95, 113
Schambow, Thomas J.	60, 141
Schantz, Merilynn	10
Schraer, Stephen M.	76
Schutte, Brian J.	49, 51, 55
Schutte, Brian J.	28
Scianna, Joe	10
Sebastian, Derek J.	16, 150
Sebastian, Scott	137

Seipel, Tim F.	143
Siblani, Walaa A.	47
Skaer Thomason, Meghan J.	9
Slesak, Robert A.	101
Sleugh, Byron B.	78
Sohn, Soo In	144
Soni, Neeta	140
Sosnoskie, Lynn M.	27, 97, 145
Spandl, Eric P.	111, 133
Spring, John F.	15, 37
Squires, Caleb C.	37, 146
Stahlman, Philip W.	135
Stahlman, Phillip W.	151, 153
Stapleton, James J.	19, 72
Stevens, Nicole O.	19
Steward, Bruce V.	40, 41, 81, 136
Strachan, Stephen	137
Sulser, Allan	18
Swain, S. Andrew	73
Swanson, Scott E.	41
Tautges, Nicole	82
Thilmony, Blake M.	11
Thilmony, Blake M.	127
Thompson, Curtis	154
Thompson, Curtis R.	135

Thornton, Michael L.	53, 114
Tidemann, Breanne	142
Todd, Olivia E.	3
Torigoe, Stacey K.	102
Tranel, Patrick	4, 121, 153
Trepanier, Andre	137
Umeda, Kai	24, 77
Vail, Gordon D.	76
Van Wychen, Lee V.	69
VanDam, David A.	111, 133
Vanderpool, Kimberly	52
Varanasi, Aruna	1
Vogt, Mark	137
Wada, Nami	144
Walsh, Michael J.	140
Wang, Guangyao	131
Westra, Eric	153
Westra, Philip	4, 34, 52, 59, 85, 119, 121, 122, 140, 153
Whitesides, Ralph E.	18, 130
Willden, Samantha A.	20
Williams, Robert W.	41
Wilson, Robert	156
Wirth, Devin A.	94
Wood, Clay W.	17, 96
Woolf, Thomas E.	106

Workman, Julia M.	96, 147, 148
Yenish, Joseph	88, 109
Yenish, Joseph P.	68
Zollinger, Rich	44, 94, 115
Zuger, Rachel J.	37, 146

WSWS 2016 ANNUAL MEETING – KEYWORD INDEX

Index of keywords and the numbers of the abstracts where they appear.

2,4-D	24, 31, 80, 106, 108, 111, 116, 126, 151
ACCase resistance	30
Acetochlor	79
Acroptilon repens	5
Adjuvants	94, 134
Aegilops cylindrica	16, 82
Allium cepa	21, 73, 74
ALS resistance	30
Amaranthus palmeri	52
Amaranthus retroflexus	79
Aminocyclopyrachlor	11, 102, 147, 148
Aminopyralid	100, 102, 125, 126, 147
Application timing	45, 74
Application, aerial	103
Application, basal bark	10
Application, fall	147
Application, ground	106
Application, methods	102
Application, sequential	102, 114
Application, spring	147
Aquatic environment	106
Aquatic weed	106

Arbuscular mycorrhizal fungi (AMF)	21
Arctium minus	124
Areas, natural	10, 13, 102, 103, 125, 126
Avena fatua	82, 86, 88, 90, 142
Barley	82
Bean, dry	46, 112, 113, 114
Bermudagrass, turf	77
Beta vulgaris	21, 48, 60, 79, 141
Bicyclopyrone	76
biochar	22
Biodiversity	10, 143
Biological control	127
Biological control agents	20, 127
Biology, weed	63
Brassica napus	80
Brassica napus	144
Brassica rapa	144
Broadleaf	13
Bromoxynil	80, 108, 111
Bromus japonicus	16
Bromus tectorum	5, 16, 17, 63, 82, 90, 96, 143, 150
Butomus umbellatus	106
Canola	42
carbohydrate partitioning	60
Carryover	42

Chenopodium album 79, 134

Chickpea 42, 45

Chlorsulfuron 2, 147, 148, 151

Cicer arietinum 45

Cirsium arvense 82

Clethodim 30, 86

Clopyralid 108, 116

Clover 50

Clover, white 50

Competition 82, 101, 149

Conium maculatum 124

Conservation, agricultural 79

Control 140

Convolvulus arvensis 73, 82

Conyza bonariensis 31

Conyza canadensis 31

Copy Number Variation 153

Corn 46

Costs 104

Cucurbita maxima 21

Cynodon dactylon 77

Cynodon transvaalensis 77

Cynoglossum officinale 124

Cyperus esculentus 74

Cytisus scoparius 101

Degree-day modeling 20

Delphinium geyeri 148

Desirable species 11

detection 8

Detection 124

Dicamba 24, 64, 80, 108, 126, 134, 151

Dichlobenil 125

Diflufenzopyr 80, 125, 126

Dimethenamid-P 74, 79, 83

Diquat 31

Direct seed 79

Ditches, ditchbanks 10

Dose-response 64

Drift, spray 92

Dry beans 44

ecological thresholds 17

Ecology, weed 10, 148

Elaeagnus angustifolia 10

Environmental compliance 104

EPTC 79

Equisetum hyemale 48

eradication 8

ET 23

Ethofumesate 79

Euphorbia esula 125, 126, 127

Evapotraspiration 23

Evolution 153

Exotic weed 10

Extension 96, 134

Fagopyrum esculentum 108

far-red light 141

Fenoxaprop 86

Fertility 23

Fescue, tall 83

Festuca spp. 83

Fir, Douglas 101

flazasulfuron 77

Fluazifop-P 30, 86

Flucarbazone 86

Flufenacet 83

Flumioxazin 131

Fluroxypyr 24, 108, 111

Fomesafen 45

Forage 105

Foramsulfuron 77

Forest 100, 101, 124

Forest, management 101, 102

Fragaria x ananassa 22

Fragment Analyzer 4

Garbanzo bean 45

Genetic analysis	118, 121
Genomics	121
Geographic information system (GIS)	7, 124
Geranium robertianum	100
Germination	64
Global positioning system (GPS)	7
Glufosinate	31
Glyphosate	4, 10, 30, 52, 79, 92, 93, 100, 102, 116, 118, 151, 153
Glyphosate Resistance	153
Glyphosate resistance	64
Glyphosate resistance	30
Grass establishment	149
Greens, golf	23
Groundcovers	24
growth	141
Guayule	131
Habitats, disturbed	10, 47, 102
Habitats, natural	10, 11, 17, 106
Habitats, semi-natural	10, 106
Halosulfuron	24
Harvest	140
hay mulch	22
hemp mulch	22
Herbage	105
Herbicide Ballistic Technology	8

Herbicide carryover 46

Herbicide concentration 116

herbicide ecology 17

Herbicide metabolism 2, 139

Herbicide mode of action 139

Herbicide resistance 2, 31, 64, 83, 111, 116, 118

Herbicide response 11

Herbicides 44

Hibiscus trionum 113

HSOC 94

image analysis 5

Imazamox 106

Imazapic 16, 17

Imazapyr 100, 106

imazethapyr 144

Indaziflam 16, 83

Insect-plant interactions 20

Integrated pest management 73

Integrated weed management 142

Invasive species 7, 101, 102, 127, 149

invasive weeds 17

inventory 6

Iris Yellow Spot Virus 73

Irrigation drip 74

Isatis tinctoria 124

IYSV	73
Kochia scoparia	2, 4, 52, 111, 121, 153
kurapia - Lippia nodiflora	24
Lactuca serriola	73
Landscapes	17, 23, 24
Late season	113
leafy spurge flea beetle	127
Lentil	42
Limited irrigation	46
Linaria dalmatica	20, 147, 148, 149
line-point intercept	5
Linuron	26
Litigation	104
Lolium multiflorum	30, 88, 90
Lolium perenne	77, 83
Lolium perenne ssp. *multiflorum*	83, 118
Malva neglecta	73
MCPA	80
Mecinus janthiniformis	20
Mentha spp.	50
Mesosulfuron-methyl	30, 42, 90
Metribuzin	26, 47
Metsulfuron	147, 148
Miconia calvescens	8, 103
Minor Crops	76

Mint	50
Modeling	20, 142
Monitoring	5
Mulch	21, 22
National Park	7, 102, 125
Native forb response	11
Native prairie response	11
Natural products	139
Nitrogen	23
Non-crop	111
Non-native plants	102
Non-target species	11
Noxious weed	100, 126
Onion	21, 73
Onion, dry bulb	74
Orchards	30, 118
organic weed management	82
Oxyfluorfen	131
Palynology	52
paper mulch	22
Paraquat	30, 45, 50
paraquat resistance	30
Parks	23
Parthenium argentatum	131
Pea	21

Pea, dry	42
Pendimethalin	131
penoxsulam	77
perennial grass	149
Pesticide use analysis	104
Phaseolus vulgaris	114
Phenology	20
Phytotoxicity	131
Picloram	126
Pinoxaden	86
Pinus radiata	7, 102
Pisum sativum	21
Poa annua	77, 83
Poa pratensis	23
Poa trivialis	83
Pollen	52
Polymorphism	4
Population genetic	4
Population Genetic	153
Potato	26
Potato tuber	75
Potato, white	47, 75
Prairie	13
Pronamide	77
Pseudotsuga menzesii	101

Public lands	104, 126
Pyraflufen	45
Pyrasulfotole	80
Pyroxasulfone	83, 89
Pyroxsulam	42
Quinclorac	125
Rangeland	5, 6, 11, 13, 20, 96, 105, 124, 126, 127, 143, 147, 148, 149, 150
Remote sensing	7
resistance	86
Rimsulfuron	26, 31, 75
Riparian areas	125
rotational crops	82
Rotational crops	42
Row spacing	114
Ryegrass, perennial	77, 83
s-metolachlor	74, 131
Saflufenacil	45, 50, 151
Secale cereale	150
Secale cereale (rye, feral)	16
Seed	140
Seed certified	113
Seedbank	127
seeding	149
Setaria glauca	88

Setaria viridis	79, 86, 88
shade avoidance	60, 141
Site Susceptibility Modeling	12
Soil Seed Reserve	150
Soil types	10
Solanum tuberosum	26, 47, 75
soluble carbohydrates	60
Sorghum	111
Spatial genetic structuring	118
Sporopollenin	52
Squash, winter	21
SSR Markers	153
SSR markers	4
starch	60
strategic weed management	17
Strawberry	22
Sugar beet	48, 79
Sulfentrazone	45, 116, 131
Sulfosulfuron	24
Taeniatherum caput-medusae	6, 16
Tamarix ramosissima	10
Taraxacum officinale	23
Taraxacum vulgare	23
Targeted Grazing	148
Technology transfer	96

Thiencarbazone	42
Thifensulfuron-methyl	90
Thrips tabaci	73
Transition, spring	77
Triclopyr	10, 103
Trifloxysulfuron	77
Trifolium repens	23
Trifolium repens	50
Trifolium spp.	50
Triticum aestivum	2
Triticum aestivum	63, 86, 90
Turfgrass	23
Turfgrass	23, 77
Vegetables	21
Ventenata dubia	16
Vernalization	63
Vineyard	118
Vulpia myuros	90
Weed	140
Weed abundance	124
Weed control	44
Weed Inventory	124
Weed management	5, 20, 48, 111, 114
Weed suppression	149
Wetlands	106

Wheat	42, 63, 82, 86, 90, 92, 108, 111
Wildfire	143
Wildfire management	143
Wildland	105
yield	141

WSWS 2016 ANNUAL MEETING – ABSTRACT NUMBER, PAGE NUMBER INDEX

001, 1	026, 15	051, 29
002, 1	027, 15	052, 30
003, 2	028, 17	053, 30
004, 2	029, 18	054, 31
005, 3	030, 18	055, 31
006, 4	031, 19	056, 32
007, 4	032, 19	057, 32
008, 5	033, 20	058, 32
009, 5	034, 20	059, 33
010, 5	035, 20	060, 33
011, 6	036, 21	061, 34
012, 6	037, 22	062, 34
013, 7	038, 22	063, 35
014, 8	039, 23	064, 35
015, 8	040, 24	065, 36
016, 8	041, 24	066, 37
017, 9	042, 24	067, 37
018, 9	043, 25	068, 38
019, 10	044, 25	069, 39
020, 11	045, 26	070, 43
021, 11	046, 26	071, 44
022, 13	047, 27	072, 55
023, 13	048, 27	073, 55
024, 14	049, 28	074, 56
025, 15	050, 28	075, 57

076, 57
077, 57
078, 58
079, 58
080, 59
081, 60
082, 60
083, 60
084, 61
085, 62
086, 63
087, 63
088, 63
089, 64
090, 64
091, 78
092, 79
093, 80
094, 80
095, 81
096, 81
097, 82
098, 44
099, 45
100, 45
101, 46
102, 47
103, 47
104, 47
105, 48
106, 48
107, 49
108, 65
109, 66
110, 66
111, 67
112, 67
113, 68
114, 68
115, 69
116, 82
117, 82
118, 83
119, 83
120, 83
121, 84
122, 84
123, 49
124, 50
125, 50
126, 51
127, 52
129, 91
130, 91
131, 69
132, 71
133, 71
134, 72
135, 72
136, 73
137, 73
138, 85
139, 85
140, 86
141, 86
142, 87
143, 88
144, 88
145, 89
146, 90
147, 53
148, 53
149, 54
150, 54
151, 73
152, 74
153, 75
154, 75
155, 76
156, 77
157, 78

2015-2016 WSWS Standing and Ad Hoc Committees

Board contact/(year-rotating off)

Awards -*President*
Carol Mallory-Smith (2016)
Alan Helm, Chair (2017)
Roger Gast (2018)

Fellows and Honorary Members - *Past President*
Tim Miller, Chair (2016)
Jill Schroeder, Chair (2017)
Kassim al-Khatib (2018)

Finance - *Member at Large – Public Sector*
Fara Brummer, Chair (2016)
Jesse Richardson, Chair (2017)
Stephen Valenti (2018)

Herbicide Resistant Plants
Member at Large – Private Sector
Brian Jenks, Chair (2016)
Prashant Jha (2017)
Marie Jansieniuk (2018)

Program - *President-Elect*
Kirk Howatt, Chair (2016)
Jan Mangold (2016)
Sandra McDonald (2016)

Publications - *President-Elect*
Kirk Howatt, Chair
Bill McCloskey, Proceedings
Traci Rauch, Research Prog. Report
Carl Libbey, Newsletter Co-Editor
Phil Banks, Website Editor

Education
Education & Regulatory Section Chair
Sandra McDonald, Chair (2016)
Andy Hulting (2016)
Mayank Malik (2017)
Randall Violett (2017)
Ian Burke (2018)
Carol Mallory Smith (2018)

Student Paper Judging - *President-Elect*
Don Morishita (2016)
Ryan Rector, Chair (2017)
Joel Felix (2018)

Legislative - *WSSA Representative*
Chad Clark (2016)
Fred Raish, Chair (2017)
James Leary (2018)
Lee Van Wychen, Ex-officio

Local Arrangements - *President-Elect*
Daniel Curtis (2016)
Brian Schutte, Chair (2017)
Monte Anderson (2018)

Necrology - *Secretary*
Steve Valenti (2016)
Ralph Whitesides, Chair (2017)
Judit Barasso (2018)

Nominations - *Past President*
Chad Cummings, Chair (2016)
Scott Nissen (2017)
Steve Eskelson (2018)
Drew Lyon, Past-President

Poster - *President-Elect*
Harry Quicke (2016)
Travis Ziehl, Chair (2017)
Jared Unverzagt (2018)

Public Relations
Education & Regulatory Section Chair
Stott Howard, Chair (2016)
Rita Beard (2016)
Joan Campbell, Chair (2017)
Todd Neel (2017)
Lynn Sosnoskie (2018)
Travis Bean (2018)

Site Selection - *President*
Stephen Colbert (2016)
Charlie Hicks, Chair (2017)
Joseph Yenish (2018)

Sustaining Membership - *Past President*
Greg Dahl, Chair (2016)
Wendell Rich, Chair (2017)
Craig Alford (2018)