PROCEEDINGS

WESTERN SOCIETY OF WEED SCIENCE

Volume 75, 2022

ISSN: 0091-4487

These proceedings are dedicated to the
WSWS ad hoc History Committee:
Vanelle F. Peterson (Chair), Rod G. Lym,
Philip A. Banks, and Don W. Morishita.

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2022

PROCEEDINGS

OF

THE WESTERN SOCIETY OF WEED SCIENCE

VOLUME 75

PAPERS PRESENTED AT THE ANNUAL MEETING

MARCH 8-10, 2022

Hyatt Regency Newport Beach

Newport Beach, California

PREFACE

The Proceedings contain the written abstracts of the papers and posters presented at the 2022 Western Society of Weed Science joint annual meeting plus summaries of the research discussion sections for each WSWS 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 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, 12110 Pecos Street, Suite #220, Westminster, CO 80234 (**info@wsweedscience.org**). 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.

The WSWS would like to thank André Lucas Simões Araujo – Colorado State University who graciously volunteered his time and talents to furnish many of the award photographs included in this publication.

Proceedings Editor: Carl Libbey

GENERAL SESSION

Introductions and Announcements. Joel Felix*; Oregon State University, Ontario, OR (158)

Welcome to the 75th annual meeting of the Western Society of Weed Science (WSWS) in Newport Beach, CA. I would like to thank the WSWS Program Committee composed of Joel Felix, Chair and President-Elect; Judit Barroso, Research Section Chair; Harlene-Hatterman-Valenti, Research Section Chair-Elect; Carl Coburn, Education and Regulatory Chair; Jane Mangold, Education and Regulatory Chair-Elect; and Sandra McDonald, WSWS President, who have worked diligently to create a program that is both informative and promise to provide a stimulating experience.

Program changes and errors.
-presentation on March 8, 2022 at 2:45PM in the Weeds of Agronomic Crops section titled †Germination Response of Italian Ryegrass (*Lolium multiflorum*) to Gibberellic Acid 3 and Preemergence Herbicides in Eastern Washington Dryland Wheat Production (74), will be presented by Ian C. Burke and was not included in the student competition (student withdrew).

-Poster **A Cost Benefit Analysis of Crop Rotations in California Rice Systems.** (18) – withdrawn

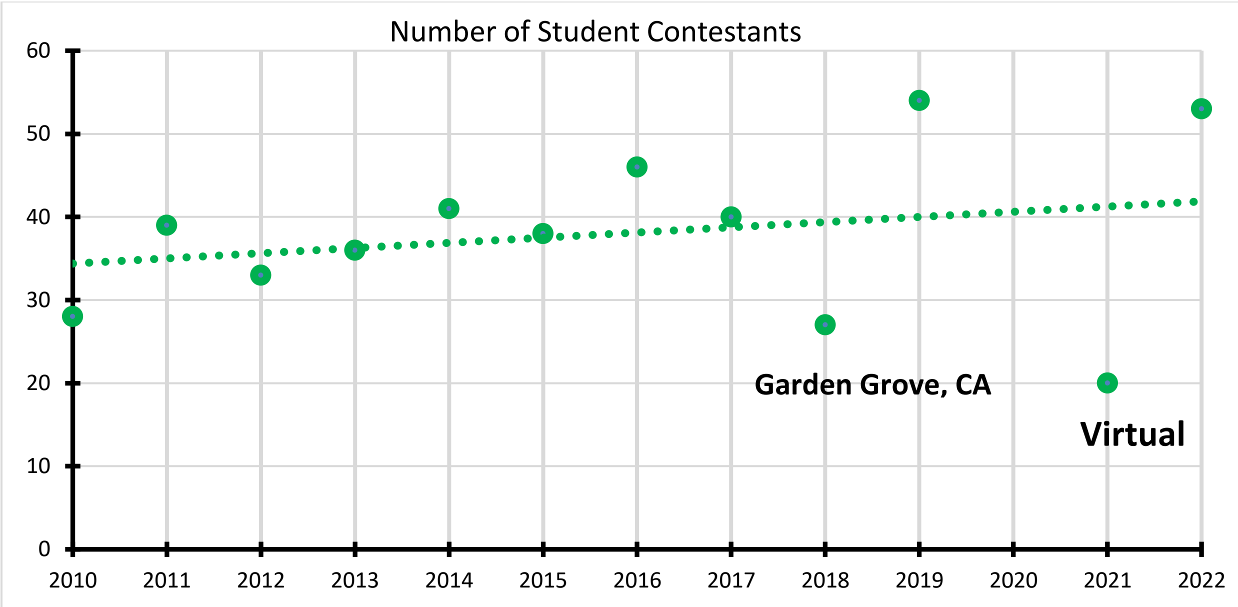
-Oral paper **Auxinic Herbicides Injury to Grapevines. (**113) - Withdrawn

The theme of the 2022 meeting was The Past History and the Future of Education and Research in the West. The meeting includes one symposium titled "New Technology for Physical Weed Control" organized by Steve Fennimore and Marcelo Moretti that will take place on Tuesday, March 8 afternoon from 1:00 to 5:00PM and one workshop titled "Weeds and Wildfires in the West" organized by Matt Baur, which will take place on Thursday, March 10, 2022 from 1:00 to 5:30PM.

The 75th meeting program includes a total of 150 paper (91 oral and 59 poster) presentations distributed among the WSWS projects, special session, plus one symposium and a workshop.

PROJECT/SPECIAL SESSIONS	ORAL	POSTERS
Weeds of Range, Forestry, and Natural Areas	20	11
Weeds of Horticultural Crops	9	11
Weeds of Agronomic Crops	32	27
Teaching and Technology	3	2
Basic Biology and Ecology	8	7
Education and Regulatory	5	1
Symposium	7	-
Workshop	7	-
TOTAL	91	59

The number of papers presented by members and students is comparable to the 2019 meeting and better than both the 2018 meeting at Garden Grove, CA and the 2021 virtual meeting.



I want to thank the WSWS project session chairs who are tasked with moderating the presentations, which entails strict time management in order to accommodate the concurrent sessions. Please make sure presentations start and end on time as indicated in the program.

Project 1: Weeds of Range, Forestry, and Natural Areas; Will Hatler, Corteva.

Project 2: Weeds of Horticultural Crops; Marcelo Moretti, Oregon State University.

Project 3: Weeds of Agronomic Crops; Nevin Lawrence, University of Nebraska, Scottsbluff.

Project 4: Teaching and Technology; Jeanne Falk Jones, Kansas State University on behalf of Brianne Tidemann, Agriculture and Agri-Food Canada.

Project 5: Basic Biology and Ecology; Rui Liu, Kansas State University on behalf of O. Adewale Osipitan, FMC.

Education and Regulatory; Carl Coburn, Bayer, chair and Jane Mangold, Montana State University, chair-elect.

Special thanks to the local arrangements committee led by Sonia Rios, Newport Beach, CA 2022, George Newberry/Albert Adjesiwor, Boise, ID (2023), and Eric Westra, Denver, CO (2024).

Heartfelt thank you to the 2022 WSWS Sustaining Members; AMVAC Chemical Corp., BASF Corporation, Bayer CropScience, Corteva AgriScience, FMC Corporation, Gowan Company, Gylling Data Management, R & D Sprayers, Syngenta Crop Protection, UPL-Ltd, Valent USA, Wilbur-Ellis Company, and Winfield United.

We are gracious to sponsors for the member and retirees reception, student breakfast, coffee breaks, luncheon, and the WSWS business meeting.

The general session program is as follows and I will serve as the moderator:

- **Presidential Address.** Sandra K. McDonald; Mountain West PEST, Fort Collins, CO
- **WSWS History: Building on the Past for the Future.** Vanelle F. Peterson; President 2011-2012
- **A Future Shaped by Our Past I: Teaching Weed Science in the West.** Andrew Kniss; University of Wyoming, Laramie, WY
- **A Future Shaped by Our Past II: Research and Extension in the West.** Jane Mangold; Montana State University, Bozeman, MT
- **DC Update.** Lee Van Wychen; WSSA – Executive Director of Science Policy, Alexandria, VA
- **Automated Weeding.** Steven Snyder; Chief Technologist, Stout AgTech, Salinas, CA

Presidential Address. Sandra K. McDonald*; Mountain West Pesticide Education and Safety Training, Fort Collins, CO (159)

Welcome to the 75th meeting of the Western Society of Weed Science.

We are honoring our past while looking forward to our future. Joel and the Program Committee put together a great program around the theme of celebrating our 75th meeting. They acknowledged the importance of reaching our 75th milestone but wanted to look to the future of the society and of weed science in general.

I am awed and honored to be able to serve WSWS as President. I keep thinking of how WSWS is our members. We are a volunteer organization and without member involvement WSWS will fail as a vibrant organization.

Thank you WSWS!!!

During our in-person Board meeting in October, the attendees were asked to use one word to describe WSWS. The most common words and phrases were:

- Characters!
- Collaborations
- Community!!!
- Diverse mind sets, coming together
- Expertise
- Friendly, welcoming interchange of information and experience
- Great, capable, friendly, hard-working people!
- Impact & jobs
- Inclusive, informative
- Member driven
- Money
- Networking
- Networking & Science
- Research ideas
- Sassy successful scientists seeking solutions
- Students!!!!!!

I truly appreciate all WSWS members, but especially those members who are willing to serve the society by being on the Board of Directors or on committees or as project chairs. I believe that the current and past Board of Directors members embody these sentiments. I want to formally recognize you and have the membership help me thank you for your service**.** Please stand up:

If you are a current WSWS Board Member
If you were a WSWS Board Member in 2021
If you are an incoming Board Member in 2022
If you have been a WSWS Board Member in the past

Thank you. Without your leadership and willingness to serve WSWS would not the accomplished organization that we are today.

I would like to thank and acknowledge our Board Members who have served their terms and will be rotating off the Board on Thursday. Please stand when I call your name:

- Corey Ransom (Immediate Past President)
- John Madsen (Secretary)
- Judit Barroso (Research Section Chair)

- Carl Colburn (Education and Regulatory Section Chair)
- John Coyle (Member at Large - Private Sector)
- Jodie Crose (Student Liaison)

My favorite part of serving as the WSWS President, has been getting to interact with our members. I started jotting down words that I heard during those conversations. Here are the ones that I heard frequently and that especially resonated with me:

- Approachable
- Aspire/Inspire
- Career
- Collaborative
- Community
- Connected
- Encouraging
- Family
- Friendly
- Fun
- Interactive
- Killing stuff!!!
- Mentor
- Network
- Opportunities
- Resources
- Respectful
- Service
- Super welcoming
- Supportive
- Team effort
- Working together

If our current set of graduate students is representative, WSWS has a bright future. I have been able to interact with several our younger members who are serving and extremely dedicated to WSWS.

Please stand up - If you were a student in the WSWS, no matter how long ago

Please remain standing if - You have or currently serve on the Board of Directors or a Committee or as Project Chair/Co-Chair

Past-President's please stand

Please stand if:

You are a WSWS Fellow or Honorary Member
You are a WSWS Outstanding Achievement Award Winner

When I think of WSWS the following words are top of mind:

- Friends
- Participation
- Service
- Support system

The members of the westerns are an amazing group. It has been an honor to serve the WSWS as president this past year. I am optimistic about the future and cannot wait to see where go and what we do next.

THANK YOU!

These past two years it has been my pleasure to serve.

WSWS History: Building on the Past for the Future. Vanelle F. Peterson*[1], Rod G. Lym[2], Philip A. Banks*[3], Don W. Morishita[4]; [1]President 2011-2012, [2]Professor Emeritus, North Dakota State University and President 1997-1998, [3]Marathon-Agriculture & Environmental Consulting, Inc., current WSWS Treasurer and President 2004-2005, and [4]Professor Emeritus, University of Idaho and President 1999-2000 (160)

Good morning. This morning I will be speaking about the history of the Western Society of Weed Science (WSWS). During the past year the WSWS ad hoc History committee worked to update the history of the society. The agenda for my talk includes: an acknowledgement of Dr. Arnold Appleby who wrote the first history of WSWS; information about the new edition of the WSWS history; the origin of Weed Science societies in the U.S; some changes that have occurred within the WSWS; and a few extra thoughts since I spent the last year delving into our history.

Dr. Arnold Appleby was a professor at Oregon State University (OSU) and was an extraordinary individual receiving numerous teaching and research awards during his career. These include Fellow awards from four professional societies (WSWS, Weed Science Society of America (WSSA), American Society of Agronomy, and the Crop Science Society of America), three Distinguished Professor awards at OSU, and both the Outstanding Teacher Award and the Outstanding Researcher Award from WSSA. He won the Outstanding Weed Scientist Award from WSWS in 1991. Three times, the students of the Crop Science Department named him the Teacher of the Year. In addition to his research and teaching career he wrote several histories – the WSWS History 1938-1992, a history of WSSA, and several histories of the programs at OSU. We owe a special debt of gratitude to Dr. Appleby for laying the foundation upon which the ad hoc history committee built. He passed away on December 6, 2018.

In 2021, the WSWS Board of Directors formed an ad hoc committee to undertake updating the history of the society. Committee members are Vanelle Peterson (chair), Phil Banks, Rod Lym, and Don Morishita, all past Presidents and Fellows of WSWS. We completed the update called *The Western Society of Weed Science 1938-2021*. Sources used were the society Proceedings, Constitution and By-Laws, Operating Procedures, meeting minutes, committee reports, WSWS and WSSSA websites, and photographs (where available) of the Board of Directors. Also, several members helped with stories from their memories. The history is 374 pages and before reducing it for posting on the website it was about 277,000 MB. The book includes a scanned copy of Arnold's history book (1938-1992) mentioned above, additional meeting summaries and Fellow descriptions (1993-2021), histories of various parts of the society, lists of Presidents, Fellows, Editors, and award winners, and a history of herbicide company consolidations that Arnold developed, *Herbicide Company "Genealogy"*. The complete document is in an electronic format available for downloading from the WSWS website. The Table of Contents has links to each section and is searchable using 'Edit' then 'Find' in the PDF.

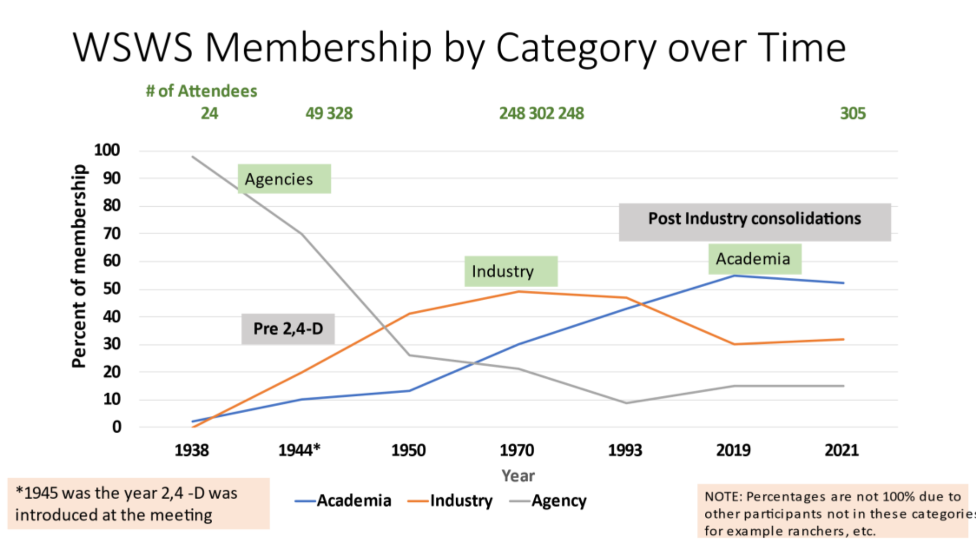
Now let's turn to the history. We can be proud that the first weed control conference in the U.S. was begun in the west. The Western Weed Control Conference (WWCC) was formed out of the Western Plant Quarantine Board (founded in 1919). The WWCC held its first conference in 1938 in Denver, Colorado. In 1968 the name of the organization was changed to the Western Society of Weed Science. Two founders of the WWCC were Harry L. Spence, Extension Agronomist and

State Seed Commissioner for Idaho, who served as President for the first 2 years, and George Hyslop, Department chair at Oregon State College who wrote the first Constitution and By-Laws for the fledgling society. It wasn't until 1945 that the North Central Weed Science Society held its first meeting and 1947 when both the Northeastern and Southern Weed Science Societies held their first meetings. All the regional societies felt that a national organization was needed so in 1958 the first National Weed Control Conference (now the Weed Science Society of America) was held.

Looking at the objectives of the WWCC in 1938 and of WSWS in 2021, it is apparent that not much has changed regarding the importance of issues. The main objectives were and still are to support education and research in Weed Science, assist agencies in understanding weed control and management of weeds, and support legislation governing weed control programs.

There have been changes though in membership, the annual meeting format, and funding the society. In 1938 there were 11 members states – Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. In 2021 there are 22 member states/Canadian provinces – Alaska, Arizona, California, Colorado, Hawaii, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, Utah, South Dakota, Texas, Washington, and Wyoming, and Alberta, British Columbia, and Saskatchewan. Our membership by organizational categories changed over time. A significant change occurred within the 3 main member categories of (1) agencies (federal, state and county), (2) industry (herbicide companies and applicators), and (3) academia (see Chart 1).

Chart 1: WSWS Membership by Category over time (1938-2021).



There is an interesting historical perspective on the Presidents of the society. From 1938 to 1960, Presidents were chosen only from agencies or academia. In fact, Lin Harris was elected President but resigned when he took a job with Chipman Chemical because industry members were not considered *"suitable to be officers"* (from the 1944 report). It wasn't until 1960 that Dick Fosse of Amchem was the first chemical industry representative to be elected President. Charlotte Eberlein, University of Idaho, was the first woman from academia to be elected President (1996-

1997). Vanelle Peterson, Dow AgroSciences, was the first woman from industry to be elected President (2011-2012).

In addition to changes in membership, there have been changes in the meeting format and use of technology over the years. In 1938 and through the 1950's, the meetings consisted of reports from state representatives about the laws regarding seeds and the control of noxious weeds. The first discussion session was held in 1941 chaired by W.W. "Doc" Robbins. This tradition of discussing current ideas and research in an open forum has continued through our meetings today and is unique to WSWS. The first research section formally started in 1946 chaired by Bill Harvey. In 1945, with the introduction of research on a new herbicide called 2,4-D, the meeting format began to change with the discontinuation of state reports and more technical papers being presented, organized by research topic, what today we call "projects". In 1963 in Portland, Oregon the first "What's New in Industry" session was held called "New Herbicides and New Uses for Old Herbicides". A poster session was begun for members with 7 posters displayed at the 1985 meeting in Phoenix, Arizona. It wasn't until 1993 that a student poster competition began.

Technology changed the way papers were presented and how we communicated with one another outside of the annual meeting. After much discussion, a website was developed in 1997 mostly from the efforts of Joan Campbell and later Tony White. In 2002, LCD projectors and laptops were used by session moderators for the paper presentations instead of 35 mm slides and slide projectors. In 2006 a graduate level mode-of-action course was added to the WSWS website thanks to Tracy Sterling, Scott Nissen, and Bill Dyer. Mail-in ballots and then on-line voting became useful along with the use of the WSSA site for abstract and presentation submission which made the job of the WSWS program chair much easier for developing the meeting program.

The WSWS wagon wheel logo first appeared on the 1993 Proceedings. It was designed by Rod Lym, Steve Dewey, and Tom Whitson with Deb Tanner, a graphic designer from North Dakota State University.

Western Society of Weed Science Wagon Wheel logo (designed by Rod Lym, Steve Dewey, and Tom Whitson)	

Fortunately for WSWS, Tom Whitson (University of Wyoming) conceived the idea for a book on the identification of western weeds to be produced and published for sales to help with finances of the society and University of Wyoming Weed Science. Tom served as chair of the group who put the photos and weed descriptions together and as Editor of the book. There were 7 original authors with 6 more members contributing through the years. The first edition was published in 1991 with the last printing (11th) in 2013 and last sales in 2017. The income from this book was critical to the financial stability of the society for many years and continues to this day with the investments made from those sales. Cumulative profit over the 28 years of sales is $290,000+ with over 190,000 copies sold.

The involvement of students increased through the years. The first student paper competition was held in 1983 and in 1993, as stated earlier, the first student poster contest was held. Since 1983 there have been over 400 students involved in the student paper and poster competitions! In 2002, then-President Jill Schroeder asked a group led by Steve Dewey and Lisa Boggs (student representative) to organize a "Student Night Out" for the 2003 annual meeting. The intent was to have members take a few students out to dinner and discuss WSWS and careers in Weed Science. This popular program continues today. It wasn't until 2006 that there was an official student representative (as a non-voting member) on the Board of Directors. But in 2008 the student liaison chair was given the right to vote as a full member of the Board of Directors. There are 2 scholarships in WSWS for student travel (1) the Elena Sanchez Outstanding Student Scholarship, funded entirely by a Student Silent Auction held at the annual meeting each year, and (2) the Rita Beard Endowment Foundation scholarship.

One extra story worthy of mention is the history of the WSWS Presidential gavel-hoe passed from President to incoming President at the end of the annual business meeting. Then-President Gus Foster (1995-1996) had a local Colorado wood worker make a wooden hoe fashioned after the short-handled hoe that was often used for weeding in lettuce and sugar beet fields in the western U.S. The first wooden Presidential gavel-hoe was passed from Gus to incoming President Charlotte Eberlein at the end of the 1996 meeting. The short-handle hoe was banned for use in many states because of its negative effects on field worker's backs and health. We can be proud that Weed Science has helped rid the use of this short-handled hoe by field workers by introducing new ways to control weeds. This Presidential gavel-hoe is a reminder that WSWS Weed Scientists can make a difference in society.

Western Society of Weed Science Presidential gavel-hoe

(photos courtesy of Phil Westra)

The committee (Vanelle Peterson, Phil Banks, Rod Lym, and Don Morishita) would like to thank all those who answered our questions, wrote short histories of parts of the society, and helped in any way with the production of *The Western Society of Weed Science 1938-2021*. It was a labor of love, and it is our hope that it will prove interesting and useful to those who come after us. We know that we leave the society in good hands.

The Western Society of Weed Science has come a long way through the years and will continue to change as our membership and the needs of members changes. Let change be the wind in our sails as we move into the future.

A Future Shaped by Our Past I: Teaching Weed Science in the West. Andrew Kniss*; University of Wyoming, Laramie, WY (161)

As we celebrate our 75th annual meeting, we want to look ***forward***. This was the clear message the WSWS Board of Directors and program committee gave to Dr. Jane Mangold and I when they asked us to present at this General Session. We need to ensure we are preparing our students well for the future. We must look to the future of weed science research and extension. But we cannot ignore the past activities of our society and our membership that has shaped who we are and who we strive to be. In preparation for this meeting, Dr. Jane Mangold and I sent a brief[1] survey to a subset of WSWS members that included a range of well-established members of our society as well as newer less-experienced members. Although we didn't plan this explicitly, the survey respondents reflected the overall makeup of our society reasonably well, with the proportion of academics, government, and private industry responses mirroring the overall membership (Figure 1).

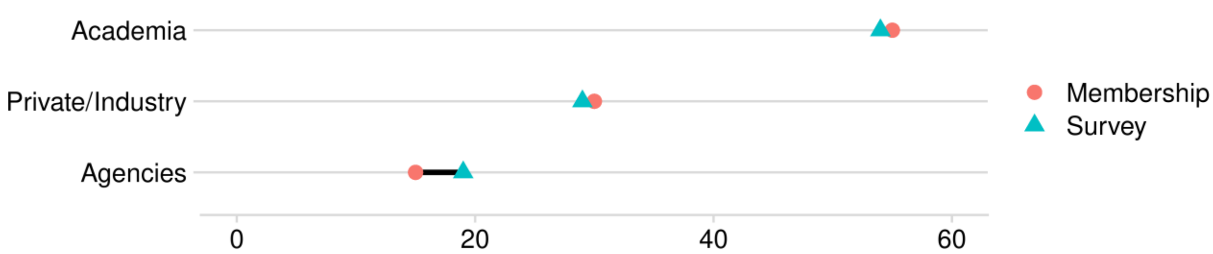


Figure 1. Affiliation of WSWS membership in 2019 as estimated by Vanelle Peterson in the foreword to the 2nd edition of the History of the Western Society of Weed Science (red circles) compared to the affiliation of survey respondents (blue triangles).

I will focus on teaching weed science, while Dr. Mangold will discuss research and extension programming, though there will necessarily be a bit of overlap, since we know these topics are impossible to cleanly separate. In preparation for this talk, I went back to a series of papers published in Weed Science in 1987 on training weed scientists for work in the public and private sectors. These papers are a summary of teaching and extension section talks given by Robert L. Zimdahl, Arnold P. Appleby, Joe Antognini, Ellery L. Knake, and Robert H. Walker & Gale A. Buchanan at the 1986 WSSA annual meeting. In particular, I want to quote Dr. Zimdahl (long time member of the WSWS), as he reviewed responses to a survey he sent out to many WSSA members (emphasis mine):

> *"Many respondents said or strongly implied that **weed science is simply too diverse**, and, thus, **it is impossible to design a single curriculum appropriate for all students**. The respondents often would add that the discipline is becoming increasingly more sophisticated, more specialized, and […] more scientific."*

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[1]The survey was not brief. It was quite long, actually. More than one respondent complained about the length of the survey and scolded us for implying it would be brief. A lot of time was spent by members of this society to complete the survey. Even those vocal members that expressed their annoyance to us completed the survey in spite of their complaints. I think this exemplifies the commitment our members have to this society.

Dr. Zimdahl also posed the question that many weed scientists have also struggled with: *"Is there not a core of essential knowledge that all weed scientists should possess?"* Rather than re-invent the wheel, Dr. Mangold and I decided to ask our survey respondents four of the exact same questions asked by Dr. Zimdahl in preparation for his talk in 1986. Those four questions related to the weed science curriculum were:

1. What courses are absolutely essential for one who will pursue a career in weed science after completing the Bachelor of Science degree?
2. What courses are absolutely essential for one who will pursue a career in weed science after completing the Master of Science degree?
3. What additional courses would you strongly recommend for a student who will pursue weed a career in weed science after completing the Bachelor of Science degree?
4. What additional courses would you strongly recommend for a student who will pursue a career in weed science after completing the Master of Science degree?

There was substantial overlap in the responses (as one might expect from the way the questions were worded). To summarize, I have combined the courses listed in response to any of the four questions to create Figure 2, which is a representation of courses that our survey respondents consider essential or strongly recommended for someone pursuing a career in weed science.

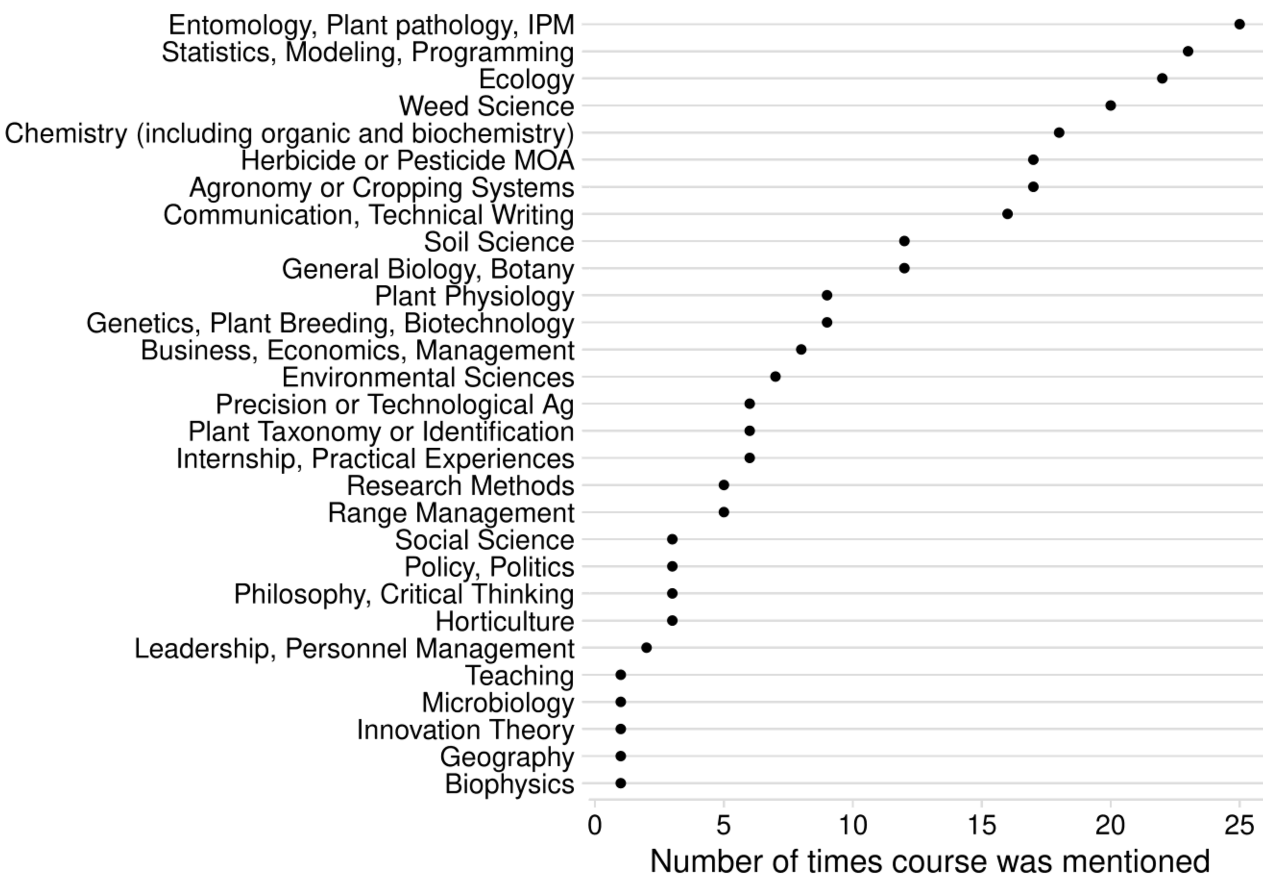


Figure 2. The number of times courses were mentioned by survey respondents in response to quetsions 1 through 4 above about essential or strongly recommended courses for students planning a career in weed science.

Of particular note, a weed science course was *not* among the top three courses mentioned for students wanting to pursue a career in weed science! I suspect that many respondents took for granted that such students would take a weed science course when answering some of the questions, and thus, weed science is probably slightly under-represented compared to respondents true beliefs. [See discussion of Figure 4, which shows that over 50% of respondents mentioned weed science at least once.] But it is worth noting which of the courses seemed to be mentioned at least as often as courses in weed science. Coursework in the other pest management disciplines (entomology, plant pathology, or integrated IPM courses) topped the list, which emphasizes the necessary cross-disciplinary education students in our society need to be successful. True 'weed science' jobs are much less common than they once were – our graduates are now hired more broadly into crop protection, seed & trait, regulatory, or land management roles where weed science is just one of the many things they'll be expected to know. This trend of a broad education shows up in most of the other items near the top of the list as well; statistics, ecology, chemistry, agronomy, and communication were all deemed important by a majority of survey respondents. The only course that would be considered 'specific' to weed science near the top of the list was a herbicide (or sometimes pesticide) mode of action course.

As another way to look at the survey response data, I grouped the responses into the same categories used by Dr. Zimdahl in 1986 (Figure 3). Since the surveys were not conducted on similar demographics nor necessarily counted and analyzed similarly, I can't conclude differences represent actual trends in thinking about weed science curriculum over time. But it is interesting, nonetheless, to compare responses from 2022 to responses collected over 35 years earlier.

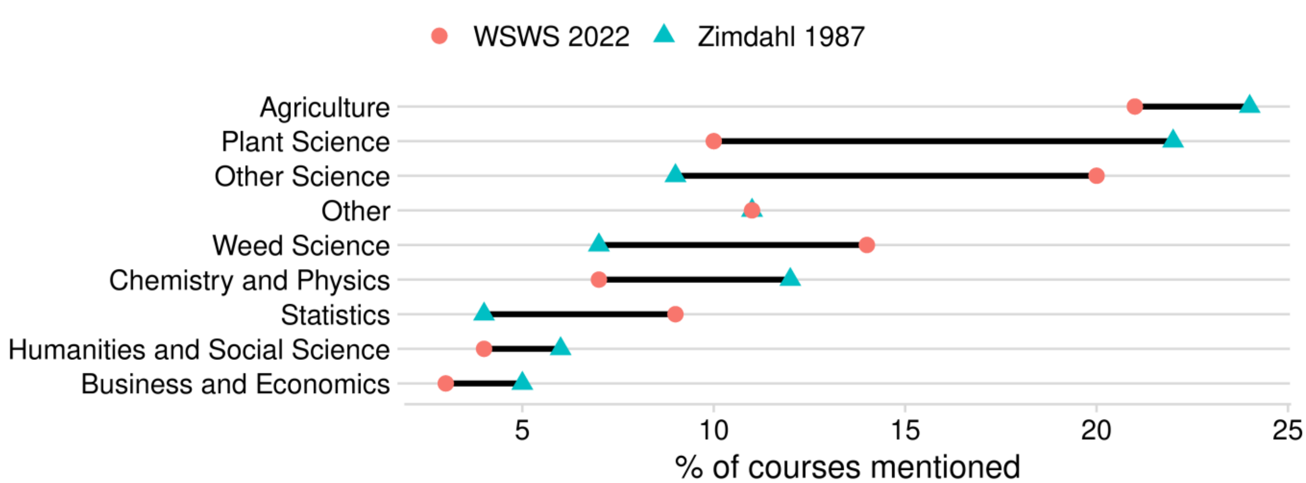


Figure 3. Coursework categories listed by respondents to surveys in 1987 (Zimdahl) and 2022 (Kniss & Mangold). Courses were placed into the categories used by Zimdahl, and presented as a percentage of total courses mentioned.

By far, the top two categories of coursework mentioned in 1986 were agriculture and plant science courses (Figure 3). Agriculture remained the top category in our 2022 survey, but ‘other science’ far exceeded ‘plant science’ courses among our 2022 responses. This is quite possibly due to the way I categorized courses; since genetics and ecology are generally more broad than just plants, I categorized these courses into the ‘other science’ category. Ecology and genetics were mentioned far less 35 years ago, but current genetics and ecology courses comprise a LOT of plant science. So the reduction in ‘plant science’ courses is probably not a true reduction in emphasis on plants, but rather a broadening of our discipline to recognize that much of what we need to know about plants can be found in broader coursework.

One final way to look at the coursework questions was in the percentage of survey respondents who mentioned specific courses (Figure 4). Among our 2022 respondents, the pest management and statistics/programming courses were the most regularly mentioned courses (in addition to weed science). Weed science showed up less often in 2022 compared to the Zimdahl 1987 survey, whereas statistics and IPM courses were noted more often by the 2022 respondents. Plant physiology, soil science, and chemistry were also noted less often by the 2022 respondents compared to Zimdahl’s 1987 report.

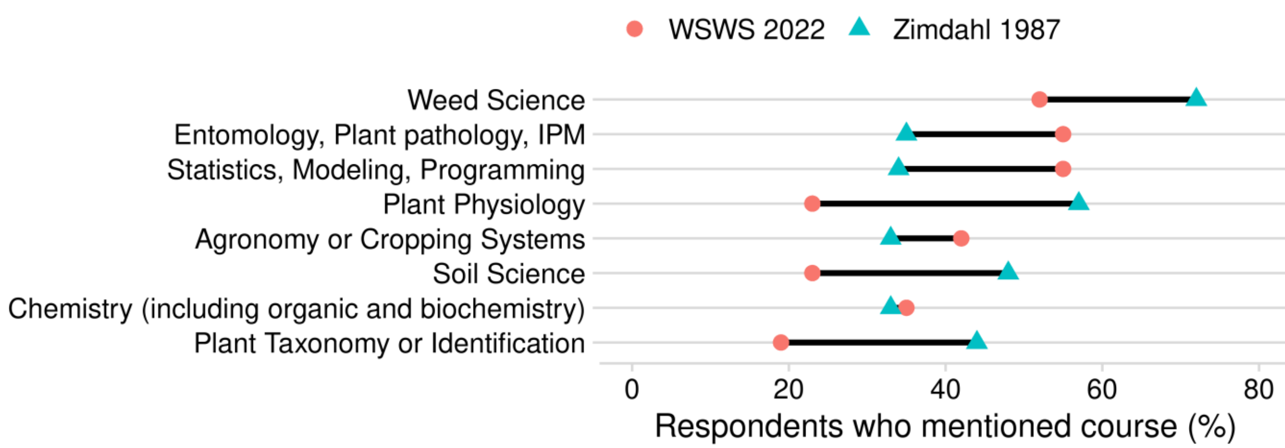


Figure 4. Percentage of survey respondents from 1987 and 2022 mentioning specific courses as being essential or strongly recommended for a career in weed science.

For the rest of my presentation, I’d like to focus on responses to another curriculum related question: ***Do you think weed science should be its own curriculum or integrated with other curricula?*** This question elicited some of the most thoughtful and thought-provoking answers related to education. Approximately 73% of our respondents provided answers that either explicitly or implicitly made a strong argument for either a standalone weed science curriculum or for integrating weed science into other programs; and among that 73%, the responses were evenly split (Figure 5).

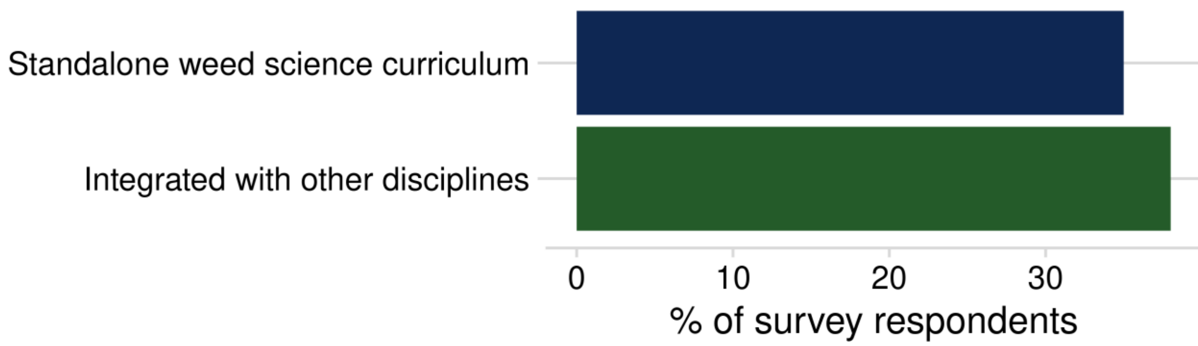


Figure 5. Percentage of survey respondents who felt weed science should be either a standalone curriculum or integrated with other disciplines. 27% of respondents did not voice support for one option or the other.

As I read through the responses, I identified three themes that were commonly expressed by our members (there were actually more than three themes, but the program committee has refused my request for a 2-hour time slot to discuss them all). Below, I have provided these three themes, along with some example responses – some direct quotations, some paraphrased – that illustrate the reasoning behind the preference for either a standalone or integrated weed science curricula.

Theme 1: Reduced weed science capacity can not sustain a standalone curriculum

- "…there's significantly fewer weed scientists at universities in the West. As a result there's really 1 weed science class at most of the universities in the west, and maybe a herbicide physiology class. We don't teach enough courses in weed science to be a strong standalone curriculum."
- Multiple respondents noted that the pest management disciplines together may be a more feasible curricula compared to standalone weed science.

Theme 2: Weed science will become diluted and less focused if integrated

- "Agricultural losses are too great to have it integrated into other courses. If Weed Science is integrated into other curricula then it becomes secondary to Entomology and Plant Pathology."
- "Now more then ever Weed Science should be its own curriculum. 20 years ago, weed science revolved around agriculture production. Now with the recognition of the impacts on wildlife and wildfire, its even more important that it stands alone."

Theme 3: The challenges facing weed scientists require multidisciplinary expertise

- "I think we should be wary of making weed science a unique curriculum and losing sight of the interconnectedness and complex nature of our natural and social systems."

- “I think many of the problems require multiple disciplines to solve and involve both educators and practitioners. If solutions require systems approaches, student training should include systems approaches that include both holistic and reductionist approaches.”
- “Weed science should be integrated with the range /wildlife management curriculum.”
- “Weeds are a part of the cropping ecosystem and we need to be able to think about the bigger picture.”

I will end with some of my own thoughts, informed by some of the thoughtful responses to this survey as well as many discussions with colleagues over the years. First, I believe (and I think many of you agree) that weed scientists tend to be ‘generalists’ who can take positions as agronomists, ecologists, and more. This has long been a strength of our discipline. I’ve often said that the weed scientists make the best [____ists] (fill in the blank with biolo-, agronom-, ecolog-, and probably more). So my question is would a standalone weed science curriculum be able to train more weed scientists to fill these diverse roles? But, perhaps, it is the generalist nature of trained weed scientists a ***result*** of not having devoted weed science programs? If we create more standalone weed science training programs, would we lose this broad training, and thus diminish our ability to fill such diverse roles?

I have heard loud and clear from both academic and industry colleagues that we need more trained weed scientists. There are consistently smaller applicant pools for weed science faculty/R&D positions compared to similar positions in other disciplines. Should we create more standalone weed science training programs be able to train more weed scientists to fill those needs? I think, especially in the West, that a standalone weed science training program could be successful in retaining much of the diverse training that weed scientists value. This comment from a survey respondent summarizes why: *“The diversity of crops & ecosystems gives students and early career scientists who train in the western US value at the global scale.”*

In my opinion, this discussion boils down to these two questions:

- If we pursue a standalone weed science curriculum: How do we maintain the broad training that encompasses the diversity of the western region if our curriculum becomes more explicitly devoted to weed science?
- If we integrate weed science into other programs: How do we ensure that weed science concepts are incorporated into the diversity of training needed if we don’t have a curriculum devoted to weed science?

Unfortunately, I don’t have answers to these questions. I think finding balance to maintain diverse training with appropriate focus on important weed science principles will require collaboration across institutions, especially in light of the reduced weed science faculty capacity across academia. Weed scientists are notably collaborative in research and extension efforts. We should consider ways to increase collaborative efforts in our teaching.

When asked about the critical components to a good weed science education (in addition to coursework), respondents focused heavily on teachers and mentors:

- *"Dedicated instructors that want to teach and inspire students to become weed scientists."*
- *"A good advisor and a good thesis project."*
- *"Understanding others' experiences can allow someone to give broader context to students. We all can benefit from the stories of others."*

Finally, among the most consistent thread I observed across several questions in the survey responses was a strong desire not to lose our applied focus on solving real problems. Some of these responses were related to research or extension, but I think are particularly relevant when discussing training of the next generation of weed scientists. A selection of responses from the survey regarding this point:

- *"Emphasis in with actionable concepts. Not simply the ecology and impacts of weeds, but practicable knowledge on how to mitigate their impacts."*
- *"Practical knowledge included on pesticide modes of actions and non-target impacts."*
- *"Need to understand the constraints & ambitions that influence practitioners."*
- *"Growers need people to solve current issues and industry needs help developing new solutions for emerging problems."*
- *"Many Universities have move away from field-based education and more toward lab and greenhouse education."*
- *"Lack of support from land grant universities for their weed programs."*
- *"Land Grant institutions have moved away from the original objectives and decreased the amount of research to support farmers and ranchers."*

I truly feel that regardless of how we approach the future of weed science education, this is the part of our past that we must embrace. We are, and have always been, scientists who solve problems.

A Future Shaped by Our Past II: Research and Extension in the West. Jane Mangold*; Montana State University, Bozeman, MT (162)

The practice of weed science in western North America is characterized by diversity, including diversity among landscapes, cropping systems, environmental conditions, cultures, and other facets of weed biology, ecology, and management. This diversity presents challenges for managing weeds because we are living and operating in complex systems. The Western Society of Weed Science (WSWS) has a long history made strong by dedicated and committed people. People are key to our success, and members of WSWS are known for their passion, dedication, collaboration, leadership, servanthood, and kindness. Dr. Andrew Kniss and I surveyed a sub-set of these dedicated WSWS members, most of whom have been in leadership roles in the society over time, asking for their input on the past and future of weed science teaching, research, and Extension. Dr. Kniss' presentation focused on teaching; this presentation focused on research and extension and combined responses to the survey with my own experiences and observations as an Extension specialist and researcher.

When asked about areas of research that have been settled or exhausted, a resounding majority of survey respondents indicated that we haven't settled or exhausted any areas of research (Figure 1). This is not surprising given the diversity of challenges concerning weed science in the West. Some other areas of research were mentioned by multiple people. "Herbicide resistance," "genetic basis for herbicide resistance," and "biological control" were equally mentioned. While at first these responses could be offensive to members who work in this arena, it is important to note that there was clarifying text along with the words and phrases presented in the word cloud (Figure 1). For example, some context behind "genetic basis for herbicide resistance" included that there has been a lot of funding dedicated to this perhaps at the expense of funding for more applied research, and that the application of this important research could be more realized. Another phrase—"biological control"—included the context that instead of searching for new agents, we may instead want to work on ways to increase effectiveness of the agents we already have.

Future research needs (Figure 2) included some of the same themes as areas of research exhausted or settled (Figure 1). This was exemplified with "genomics," which was the most mentioned future research need. "Systems level" was a major research theme for the future. "Systems level" included considering weeds in the broader context of how weeds interact with other organisms in the environment, including other pests like insects and diseases, but also the environment itself like interactions with soils, agronomic practices, grazing and climate. Advances in a variety of technologies over recent years shows up as "precision technologies." This promises to remain and become and even bigger research area in the future, and an area where WSWS can be a leader as exemplified with a general session talk yet to come and the symposium "New technology for physical weed control" this afternoon.

When considering Extension weed science, survey respondents were asked to share three to five words describing Extension in the past and present. "Education" and "face to face" were most common followed by "outreach" (Figure 3). These descriptors along with "communication," "applied," "hands on," "demonstration," "field," "local," and "engaging" are all good descriptors of what Extension has been traditionally known for and what was the original intent of the creation of Extension. One word that showed up repeatedly and somewhat surprised me was “herbicide.” This could reflect that people associate Extension as providing herbicide recommendations and historically working with industry to test new products. And, while this is certainly true, and certainly what many clients expect from Extension, I was a bit disappointed that “integrated weed management,” “IPM,” or “integrated” was not mentioned at all. There were many negative words describing Extension past or present including “old fashioned,” “stale,” “messy,” “weak,” “lacking,” and “out of touch.” This is concerning and indicates room for improvement as well as room for additional investment by Land Grant Universities for this facet of their mission in the future.

Words describing what Extension weed science should be in the future included many of the same as what Extension has been in the past or present: “education,” “face to face,” “engaging,” “local,” and others (Figure 4). “Herbicide” was not mentioned by any survey respondents, and “integrative” appeared. Two other words that appeared for the future include “virtual” and “digital.” Moving forward, a balanced approach between face to face, which is what Extension has been known and valued for for decades, and virtual is necessary. There has been movement toward a more virtual presence over the last decade, and the pandemic forced Extension to move more in this direction. How can we do this effectively as we move forward? I propose using virtual programming to provide basic information through presentations, readings, and directing clientele to other online resources. Then, we use face to face programming to discuss more in-depth information, conduct hands-on activities, share field experiences, and conduct participatory research. A couple additional thoughts regarding future Extension weed science: provide clientele with action-based information that is less focused on technical information and more focused on actions to take to minimize impacts associated with weeds (e.g., clean your gear and equipment to stop weed seed spread), have more frequent interaction with clientele but provide less content per individual interaction (e.g., social media posts), and empower clientele to do their own on-farm/on-ranch research to inform site-specific management.

As we move toward a future shaped by our past, let’s celebrate the diversity that the West offers. This diversity offers challenges but also great opportunity. Let’s celebrate the people who are part of WSWS and the people who are served by WSWS. Let’s continue to collaborate. Let’s expand the application of our teaching, research and Extension to the improvement of weed management, and let’s keep growing and aiming high.

Figure 1. Word cloud of responses to survey question "Please list any areas of weed science research that you think have been settled or exhausted and briefly explain why." The larger a word or phrase, the more frequently it was mentioned in a survey of a subset of WSWS members.

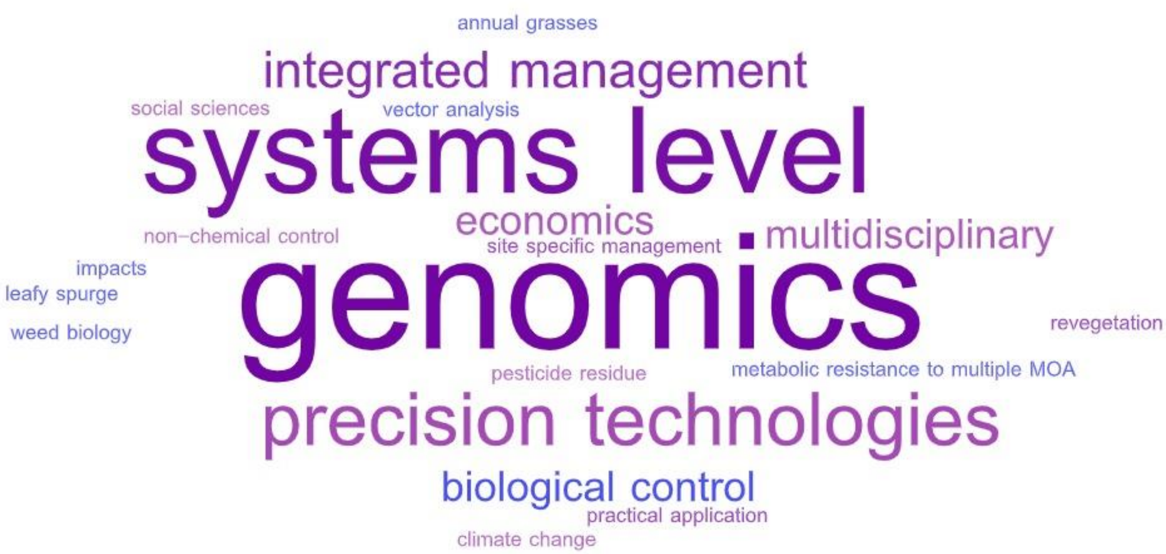
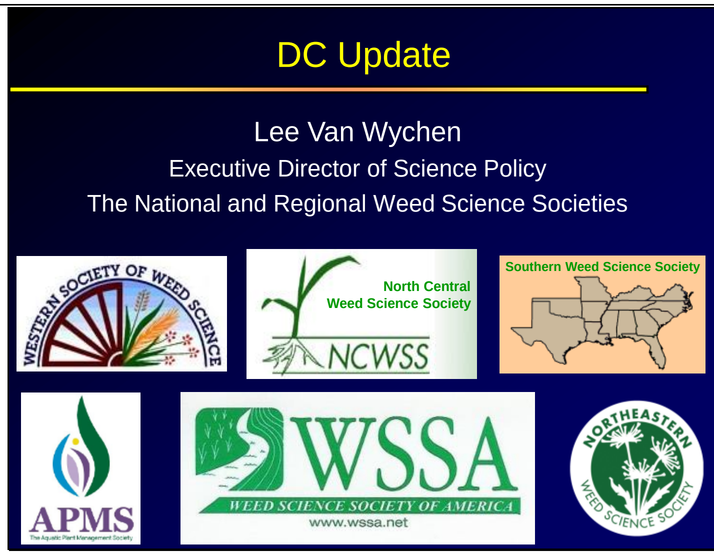


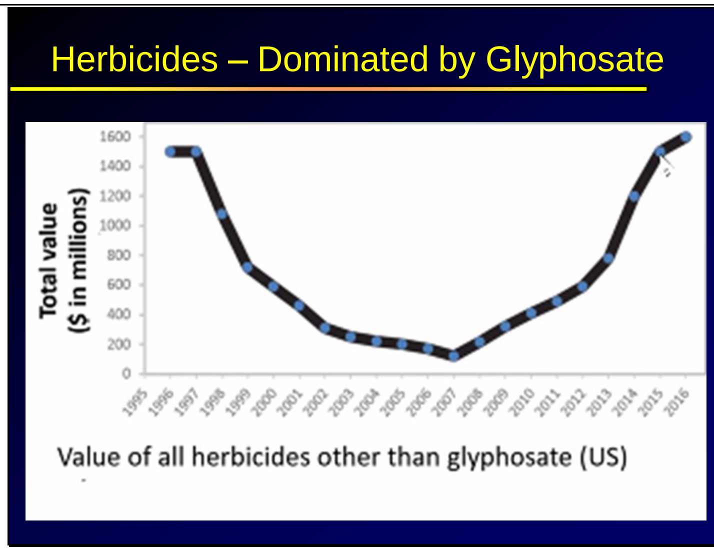
Figure 2. Word cloud of responses to survey question "Please list any areas of weed science research that are needed in the future and briefly explain why." The larger a word or phrase, the more frequently it was mentioned in a survey of a subset of WSWS members.

Figure 3. Word cloud of responses to survey question "List three to five words that you feel describe weed science extension in the past or in its current form." The larger a word or phrase, the more frequently it was mentioned in a survey of a subset of WSWS members.

Figure 4. Word cloud of responses to survey question "List three to five words that you feel should describe weed science extension in the future." The larger a word or phrase, the more frequently it was mentioned in a survey of a subset of WSWS members.

DC Update. Lee Van Wychen*; WSSA – Executive Director of Science Policy, Alexandria, VA (163)





Outline

1. People
2. Money
3. Regulatory
4. Miscellaneous

USDA NIFA National Program Leader for Weed Science – Vijay Nandula

Manages the Crop Protection and Pest Management (CPPM) program

Ph.D. in Weed Science and Plant Physiology from Virginia Tech.

Previously with USDA-ARS since 2011 in Stoneville, MS where he worked on herbicide resistance issues.

Email: vijay.nandula@usda.gov

USDA ARS National Program Leader for Invasive Pests of Crops – Steve Young

Ph.D. in Soil Science from the UC-Davis
M.S. in Weed Science from the Univ. of Idaho
B.S. in Horticulture from Washington State

Previously at Utah State University, Northeastern IPM Center at Cornell

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Weed Science Liaisons
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Rebecca Champagne
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Interior Secretary
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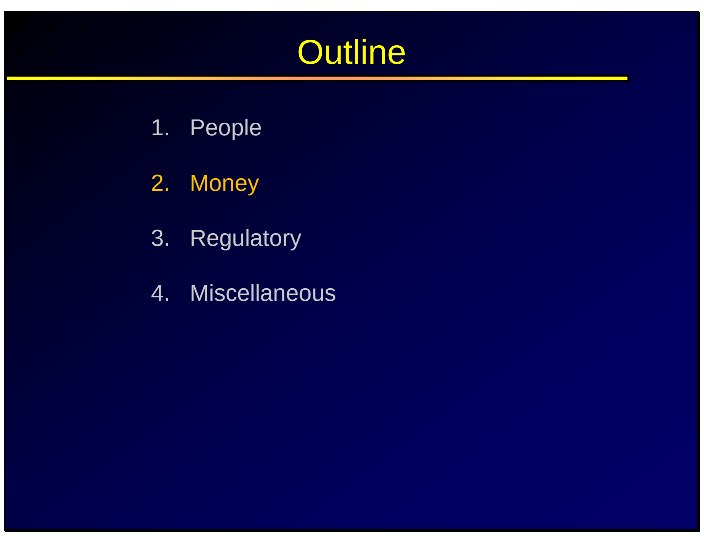
Michael Connor – NM


Outline
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FY 2022 Appropriations

- Continuing Resolution (CR) through March 11
- GOAL: Increase IR-4 funding to $25 million
  - Stuck at $11.9 million for past decade
  - The IR-4 Project contributes $9.4 billion to the annual U.S. GDP and supports more than 95,000 jobs
- GOAL: Increase Crop Protection and Pest Management (CPPM) funding to $25 million
  - Funded at $20 million since FY 2017
  - Supports Extension IPM, Regional IPM Centers and IPM research grants

2021 Infrastructure Law

- SEC. 11522. Invasive Plant Elimination Program
  - Dept. of Transportation (DOT) - $250M total
- SEC. 40804. Ecosystem Restoration
  - U.S. Forest Service - $200M for invasive species research, detection, prevention, and eradication
- SEC. 40907. Multi-Benefit Project to Improve Watershed Health
  - Bureau of Reclamation (BOR) - grants for habitat restoration that protect against invasive species

DOT Invasive Plant Elimination Program: $50M per year

- The Federal Highway Administration:
  - "*shall carry out a program to provide grants to States to eliminate or control existing invasive plants or prevent introduction of or encroachment by new invasive plants along and in areas adjacent to transportation corridor rights-of-way*"
  - The term "invasive plant" means a nonnative plant, tree, grass, or weed species, including Palmer amaranth

"Build Back Better Act" / Reconciliation Bill

- Stalled in Senate

- $27 billion for forest resiliency programs
- $2 billion for ag research
  - $210 million for AFRI grants program
  - $120 million for SARE projects

- Supported $11.5 billion in ag research infrastructure investments over five years.
  - A recent Gordian/APLU study assessed the state of facilities at U.S. colleges of agriculture and reported that 69% of these buildings are at the end of their useful life.

Outline

1. People
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4. Miscellaneous

Compliance with Endangered Species Act (ESA)

- EPA announced ESA Protection Policy for New Pesticides - effective Jan. 11, 2022

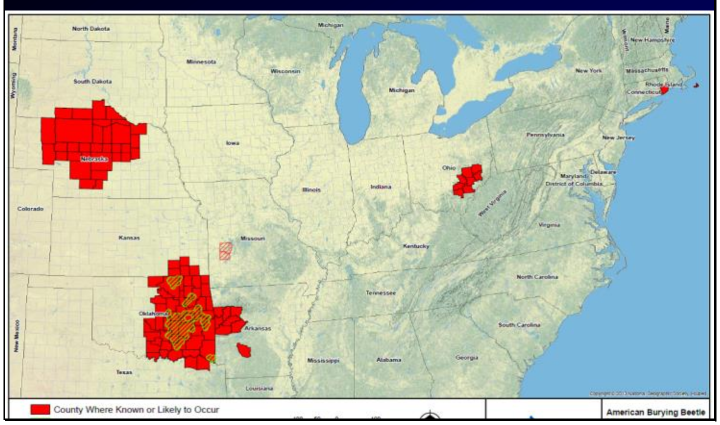
- Enlist labels announced. Enlist Duo prohibited in 217 counties in 21 states

- WSSA BOD approved ESA Special Committee

Finding Reasonable and Prudent Alternatives (RPA's)

- Measures to reduce the risk of jeopardy from a pesticide
- Currently, two main RPA's:
  - Removing a region (i.e. county) with a listed species from the label
  - Adding spray drift or runoff mitigation requirements to minimize the species' exposure to the pesticide
- Next up: glyphosate, atrazine, simazine
  - EPA released BE's in Nov. 2021
  - Glyphosate "likely to adversely affect" 1,676 ESA species and 759 critical habitats

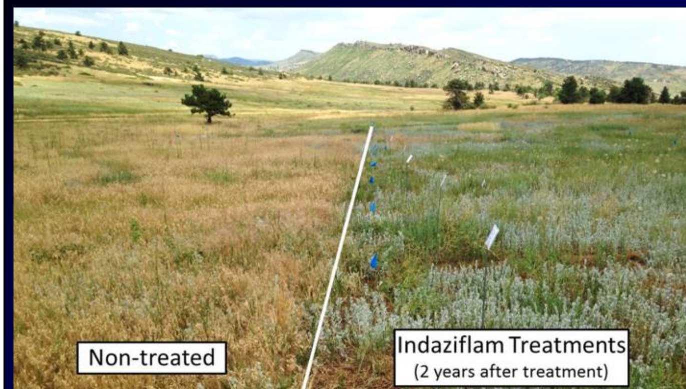
American Burying Beetle Range Map



Opposition to "anti-FIFRA" Bill: S.3283

- Protect America's Children from Toxic Pesticides Act
  - Introduced by Sen. Cory Booker - NJ
  - Would allow any person to submit a petition to designate a pesticide product as dangerous – regardless of the individual's background, motives, or scientific data supporting its safe use.
  - Any pesticide banned in the EU or Canada would be immediately banned within the U.S., even if EPA scientific reviews have determined it is safe to use.

Bureau of Land Management- NEPA Process



Cold-tolerant Hydrilla in Connecticut River. Next stop- Great Lakes?

Outline

1. People
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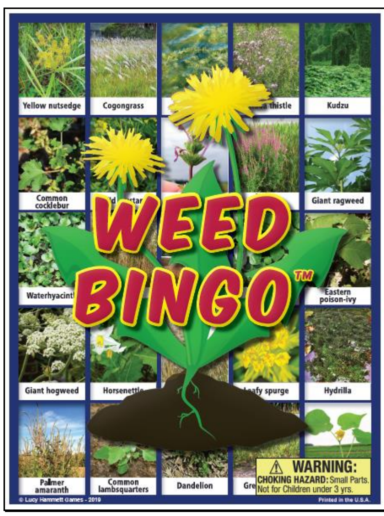
Weed Research Priorities Survey

- Survey to identify critical research priorities for advancing weed science in the next 5-10 years.
  - Provide general information on your background
  - Rank nine broad areas of weed science research
  - Prioritize research sub-categories within those broad areas of your choice.

2021 Weed Survey Results (poster 46)
Right-of-Ways: WSWS region

	MOST COMMON		MOST TROUBLESOME
1	downy brome (9)	1	kochia (8)
2	kochia (8)	T2	downy brome (6)
3	Canada thistle (6)	T2	Russian thistle (6)

2022 Survey: weeds in broadleaf crops, fruits & vegetables



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Automated Weeding. Steven Snyder*; Chief Technologist, Stout AgTech, Salinas, CA (164)

Abstract not available

POSTER SESSION

WSWS Committee Informational Posters

Necrology: WSWS Member Remembrance 2022. Ryan E. Rapp[1]*, Earl Creech[2], and Rachel Seedorf[3]; [1]Bayer CropScience, Laramie, WY, [2]Utah State University, Logan, UT, [3]Aero Applicators, Sterling, CO (153)

WSWS History Poster. Vanelle Peterson*, Past President 2011-2012, Chair (154)

WSWS Diversity and Inclusion Ad Hoc Committee: Cultivating Growth in our Society. Elizabeth G. Mosqueda[1], Chair, Albert Adjesiwor[2], Lesley Beckworth[3], Steven Haring[4], Julie Kraft[5], Vanelle Peterson[6], Sonia Rios[7]; [1]Madera Community College, [2]University of Idaho, Kimberly, ID, [3]Teton County Weed & Pest District, Jackson, WY, [4]UC-Davis, CA, [5]Sublette County Weed and Pest, Pinedale, WY, [6]retired Dow AgroSciences, Fort Collins, CO, [7]University of California, Riverside, CA (155)

Public Relations Committee. Breanne Tidemann*, Agriculture and Agri-Food Canada, Chair (156)

Revised Herbicide Mode of Action Classification. Caio Brunharo, Tom Barber, Jason Bond, Jim Brosnan, Joan Campbell, Charles Geddes, Neha Rana, Daniel Stephenson, Nithya Subramanian, Muthu Bagavathiannan; Weed Science Society of America Herbicide Resistant Plants Committee. (157)

The Global HRAC (Herbicide Resistance Action Committee) Mode of Action classification was revised in 2010 and again in 2020. The 2020 revision was needed for several reasons: Increased knowledge on the mode of action of some herbicides, the legacy lettering system was limited to 26 modes of action, and Hindu-Arabic numbers are mostly understood in geographies that don't use the Latin alphabet. Changes include the reclassification modes of action, addition of 15 new active ingredients and rationalization of chemical family names. It is expected that two-to-four new modes of action will be released within the next 10 years, and the numbering system will be able to accommodate the expansion of new modes of action in the future. The numerical code is more likely to be comprehended by a wider audience, particularly in regions of the globe with low rates of literacy. With the recent changes, the numerical code adopted aligns with the Weed Science Society of America system. Global HRAC will continue to work with countries currently using the letter-based system to transition to the number-based system. Educational efforts are in place to make the WSSA and the regional societies' membership aware of the HRAC classification updates. Information is available at https://hracglobal.com/ and https://wssa.net/wssa/weed/herbicides/.

Undergraduate Posters

Adaptive Trait Variation and Evolution of Incresed Competitive Ability in Native Perennial and Invasive Annual Grasses. Courtney R. Malmberg*[1], Jeremy James[2], Roger L. Sheley[3]; [1]Cal Poly, Natural Resources and Environmental Science Department, San Luis Obispo, CA, [2]UCANR, Browns Valley, CA, [3]USDA-ARS, Burns, OR (057)

The invasion of annual grasses on historically perennial-dominated landscapes in the Intermountain West is a serious threat to biodiversity and ecosystem function. Research has shown that functional trait differences between invasive annual grasses and native perennial species are key drivers in the invasion process; however, the degree to which functional traits have evolved in the invasion process is unknown. The objectives of this study were to examine how functional trait variation influenced growth of an invasive annual grass medusahead (*Taeniatherum caput-medusae (L.) Nevski*) and a native perennial grass squirreltail (*Elymus elymoides (Raf.) Swezey*) and to examine if medusahead functional traits have evolved in its invaded range. Growth, morphological, physiological and biomass allocation traits were analyzed in populations of squirreltail and medusahead from its native range and medusahead from its invaded range. Our results show medusahead maintains a higher relative growth rate (RGR) than squirreltail, but the mechanism appears to be different depending on origin with native medusahead achieving a higher RGR through a higher specific leaf area (SLA) and the invasive medusahead achieving a higher RGR though a higher net assimilation rate (NAR). We did not, however, find that medusahead evolved traits allowing it to grow faster or bigger in its introduced range. Instead, medusahead populations from its native range grew bigger, primarily due to substantial differences in seed sizes among populations of different origins. Smaller seed size may be a selected trait in invasive populations of medusahead, allowing greater dispersal and higher seed bank densities compared to native populations.

Cross-resistance of Conyza spp. to Auxinic Herbicides. Rafaela Cinelli[1], Felipe Bagnara*[2], Alisson M. Hahn[3], Michelangelo M. Trezzi[4], Augusto Kalsing[5], Anderson L. Nunes[6]; [1]Universidade Tecnológica Federal do Paraná - Campus Pato Branco, Passo Fundo, Brazil, [2]Colorado State University, Fort Collins, CO, [3]Instituto Federal de Educação Ciência e Tecnologia do Rio Grande do Sul - Campus Sertão, Sertão, Brazil, [4]Universidade Tecnológica Federal do Paraná - Campus Pato Branco, Pato Branco, Brazil, [5]Corteva Agriscience, Primavera Do Leste, Brazil, [6]Instituto Federal de Educação Ciência e Tecnologia do Rio Grande do Sul - Campus Sertão, Getúlio Vargas, Brazil (058)

Auxinic herbicides are important tools in the management of *Conyza* spp. Herbicide resistant populations reduces the available options of chemical control. The objective of this work was to identify *Conyza* spp. biotypes resistant to auxinic herbicides and define their level of resistance. Five biotypes of *Conyza* spp. with suspected resistance and one susceptible were submitted to a dose-response experiment with the herbicides 2,4-D, dicamba, triclopyr and florpyrauxifen. The doses for each herbicide ranged from 0 to 8x the recommended label rate. The experiment was performed in greenhouse using a completely randomized design with four replications. The herbicide doses were applied when the plants were 10-15 cm tall. Visual control and shoot dry mass were evaluated at 45 days after application. Data were subjected to regression analysis. The biotype was considered resistant when it met the following criteria: Resistant factor (RF)

significantly higher than 1, plants surviving at recommended dose (1x) and if the herbicide ratio to control 90% of the plants (C90) or reduce 90% of shoot dry mass (GR90) were higher than the recommended dose. One biotype was susceptible to all herbicides. For the herbicide 2,4-D and florpyrauxifen, all other biotypes met the criteria and were considered resistant. For the herbicide dicamba, only two biotypes did not meet the criteria. For the herbicide triclopyr, three biotypes did not meet the criteria. Two biotypes showed resistance to the four herbicides studied. Complementary studies will be performed to understand the mechanism of resistance.

Evaluating the Shade Avoidance Response of Mouse-Ear Cress Across Time Intervals. Walker T. Billings*, Joe G. Ballenger; University of Wyoming, Laramie, WY (059)

When plants are exposed to far-red light reflected from other plants, they allocate resources to stem growth in order to overtop one another and obtain light from the top of the canopy. This is called the shade avoidance response. The growth stage at which plants are exposed to far-red light is important in the shade avoidance response, as yield loss still occurs from early exposure to weeds. We therefore set out to determine whether a model weed, mouse-ear cress (*Arabidopsis thaliana*), is capable of displaying early shade avoidance responses. Mouse-ear cress was grown in a soil environment or alongside grass, with subsamples transferred from soil to grass or grass to soil at 17 days after planting. One set of plants was harvested at 40 DAP; another at 56 DAP. Although slight differences were observed in leaf count, no evidence of a shade avoidance response affecting biomass was observed in contrast to previous studies in *Arabidopsis*. Non-crop plants may show different responses to competition than crop plants.

California Weedy Rice Germination at Various Temperatures. Maya T. Delong*, Liberty B. Galvin, Kassim Al-Khatib; University of California, Davis, CA (060)

California weedy rice (*Oryza sativa spontanea*) is a unique and perpetual pest in California rice cropping systems. Weedy rice and cultivated rice are difficult to differentiate as they appear similar before panicle initiation, hindering early-season weed management efforts. To determine the difference, weedy rice biology needs investigation. This research seeks to understand the temperature thresholds of weedy rice germination in order to further understand this pest's biology. Weedy types 1, 2, 3 5, and M206 were used in this experiment. M206 is a medium-maturity, medium-grain, common rice cultivar in California. Weedy seed dormancy was broken in a dry dark growth chamber set to 50°C for five days before the experiment's start. Prepared weedy seeds and M206 were placed in separate petri dishes containing filter paper and 5 mL of deionized water then wrapped with parafilm. Petri dishes were placed in a dark growth chamber in an effort to mimic saturated soil conditions (0 mPa). Dishes were examined daily for seed germination. The experiment's temperature range was between 10 and 40°C at 5°C intervals. At 10°C, germination didn't reach above 20%, though Weedy type 5 germinated significantly more than the other weedy types. Between 15 and 35°C, weedy rice germination was above 90% with the exception of Type 3 at 15°C, which had significantly lower germination than other weedy types. At 40°C, all rice germination dropped, with M206 germination under 10%. Generally, weedy rice had more total germination at temperatures greater than or equal to 20°C and less germination below 20°C.

Education and Regulatory

Evaluating Noxious Weed Control and Vegetative Community Response Using a Standardized Monitoring Protocol. Jane Mangold*, Lisa J. Rew; Montana State University, Bozeman, MT (032)

Monitoring the outcome of noxious weed control and the response of the co-existing vegetation is often overlooked. However, interest in monitoring has increased, driven most notably by variable control and cost over the long-term, along with a greater need for environmental and fiscal sustainability. Land managers want monitoring methods they can use that are not too cumbersome to perform and provide an improved understanding of the effectiveness of their control actions including whether desired vegetation increases. For larger land areas with many noxious weed species, monitoring information can also be used to adapt and maximize the efficiency of integrated weed management programs and prioritize species. We developed a monitoring protocol to help professional and private land managers to determine the effective of their weed control measures on the target weed(s) and co-existing vegetation. The protocol has four levels that range in degree of complexity from Level 1 - for people with limited plant identification skills (estimate abundance of target noxious weed(s)) to Level 4 - for people with advanced plant identification skills (estimate abundance of target noxious weed(s) and all other species). The protocol includes information and examples of how to collect data and perform basic statistical analysis in Excel. The protocol was tested by land managers with a wide range of field sampling and data analysis skills, and improvements were made. Further evaluation of the protocol will be performed over a wide variety of rangeland habitats. Initial tests suggest the four levels provide the desired spectrum of complexity needed for a diversity of land managers and will provide sufficient statistical power to determine change in the plant community.

WSWS Project 1. Weeds of Range, Forestry, and Natural Areas

2021 Survey Results for the Most Common and Troublesome Weeds in Aquatic and Non-Crop Areas. Lee Van Wychen*[1], Devon E. Carroll[2], Rebecca Champagne[3]; [1]Weed Science Society of America, Alexandria, VA, [2]The University of Tennessee, Knoxville, TN, [3]The University of Maine, Orono, ME (046)

The 2021 Weed Survey for the U.S. and Canada surveyed the most common and troublesome weeds in: 1) irrigation and flood control; 2) lakes, reservoirs, and rivers; 3) ponds; 4) forestry; 5) parks and refuges; 6) ornamentals: field nursery crops, outdoor containers, and Christmas trees; and 7) right-of-ways: railways, roads, public utilities. Common weeds refer those most frequently seen while troublesome weeds are the most difficult to control, but not necessarily widespread. There were 289 total survey responses from the U.S. and Canada, of which 85 were from the following Western Society of Weed Science Society (WSWS) states and provinces: Alberta, Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, Oklahoma, Oregon, Texas, Utah, Washington, and Wyoming. No responses were submitted from Alaska, British Columbia, Hawaii, New Mexico, North Dakota, or Saskatchewan. The following weed survey results are specific to the WSWS region. The top three common weeds in irrigation were 1) *Stuckenia pectinata*; 2) *Cirsium arvense*; and 3) a five-way tie while the most troublesome weeds were 1) a four-way tie between *Cardaria draba*, *Convolvulus arvensis*, *Euphorbia esula*, and *Stuckenia pectinata*. The top three most common weeds in lakes were 1) *Potamogeton* spp.; 2) *Myriophyllum spicatum*; and 3) *Ludwigia* spp. and most troublesome weed a three-way tie between *Butomus umbellatus, Myriophyllum spicatum,* and *Potamogeton crispus.* The top two most common weeds in ponds were 1) *Potamogeton* spp.; and 2) a three-way tie between *Algae* spp., *Najas guadalupensis,* and *Nelumbo lutea* whereas the most troublesome weeds were a tie between *Algae* spp. and *Myriophyllum* spp. The top three most common weeds in forests were 1) *Cirsium* arvense; and 2) a tie between *Carduus nutans* and *Centaurea* spp. while the most troublesome weeds were 1) *Cirsium arvense*; 2) *Cynoglossum officinale*; and 3) a tie between *Centaurea* spp. and *Euphorbia esula.* The top three most common weeds in parks were 1) a tie between *Carduus nutans* and *Cirsium arvense*; and 3) *Bromus* spp. while the most troublesome were 1) *Cirsium arvense* followed by a four-way tie. The top three most common weeds for right-of-ways were 1) *Bromus tectorum*; 2) *Bassia scoparia*; and 3) *Cirsium arvense* while the most troublesome were 1) *Bassia scoparia*; and 2) a tie between *Bromus tectorum* and *Salsola tragus.* Only two respondents completed the survey for ornamentals. Therefore, data are not presented due to insufficient sample size. The 2021 weed survey data is available at: www.wssa.net/wssa/weed/surveys/.

Long-term Halogeton glomeratus Control with Indaziflam in Moffat County, CO US. Jacob Courkamp*[1], Paul J. Meiman[2]; [1]Colorado State University, Fort Collins, CO, [2]University of Nevada-Reno, Department of Agriculture, Veterinary, and Rangeland Sciences, Elko, NV (047)

Particularly problematic in disturbed areas with saline soils, the invasive annual forb *Halogeton glomeratus* (M. Bieb) C.A. Meyer is widespread in rangeland ecosystems in the intermountain region of western North America. High levels of oxalates in the leaves of actively growing plants make this invader toxic to livestock. While several strategies for mitigating its toxicity have been developed, heavy losses of sheep have occurred in the past and there is little doubt that usable forage is greatly reduced in areas where halogeton is dominant. Further, because halogeton can produce high numbers of persistent seeds and decaying plants often increase the salinity of soils favoring its continued dominance, restoring invaded rangelands can be extremely difficult. Indaziflam (Rejuvra®, Bayer) is a pre-emergent herbicide recently labeled for use in rangelands grazed by livestock, and while it has shown promise as a tool for managing invasive annual grasses, its potential for managing other problematic rangeland weeds remains to be investigated. We applied indaziflam at two different rates (73 and 102 g ai ha^{-1}) to halogeton-invaded rangeland in Moffat County in northwest Colorado. Treatments also included other herbicides commonly used to control halogeton, both alone and in combination with indaziflam. Follow-up evaluations 11 and 22 months after treatment showed near complete control of halogeton in all plots treated with indaziflam at either rate, regardless of tank-mix partner. Our results suggest that indaziflam may represent a promising new tool to manage halogeton, reduce its impacts, and help managers restore invaded rangelands. Additional research is necessary to replicate our findings, determine the optimal timing of application, and assess the need for follow-up treatments.

Evaluation of Tiafenacil Tank-mixed with Glufosinate for Control of Annual and Perennial Weeds in California. Guelta Laguerre and Brad Hanson, University of California, Davis. Guelta Laguerre*; University of California, Davis, CA (048)

According to the United States Department of Agriculture, California produces approximately 80% of the world's almonds and 100% of the U.S commercial almond production. Because one of the main challenges orchard managers face is weed management, postemergence and preemergence herbicides are commonly used in orchards. New herbicides are constantly being evaluated for potential registration. Tiafenacil is a new protoporphyrinogen IX oxidase-inhibiting (PPO) pyrimidinedione herbicide that is under consideration for registration for control of grasses and broadleaf weeds. In winter 2021, an experiment was conducted to evaluate solo tiafenacil compared to various tank mix rates of tiafenacil and glufosinate. Twelve herbicide treatments were evaluated in an 8-year-old almond orchard using single-tree plots in a randomized complete block design with four replicates. The experiment was repeated in a fallowed field near Davis, California in summer 2021. Ratings were made 7, 14, 28, and 35 days after treatment. The weed species present were California burclover, ryegrass, little mallow, filaree, common chickweed, common purslane, yellow nutsedge, lovegrass, black nightshade, redroot pigweed, and annual bluegrass. Data were analyzed using analysis of variance in ARM 2021, with mean comparisons using protected Least Significant Difference. Solo tiafenacil and tank mixes with glufosinate provided 90 to 100% control on all broadleaf weeds, 78% control of lovegrass, 58% control of ryegrass and annual bluegrass. While tiafenacil performs well on broadleaves due to its mode of action; tank-mixing is required for control of grasses. Tiafenacil demonstrates a potential as another option to almond's growers with studies being continued throughout 2022.

Sagebrush Tolerance at Various Growth Stages to Four Annual Grass Herbicides. Jodie A. Crose*, Brian A. Mealor; University of Wyoming, Sheridan, WY (049)

Big sagebrush (*Artemisia tridentata*), a shrub species extensively distributed throughout the western U.S., has been declining due to many factors including invasive species encroachment. Restoring this species is complicated by its low seedling competitive ability, which is exacerbated by invasive annual grass competition. Restoration of this species requires a landscape scale, cost-effective approach. A previous study revealed variable sagebrush transplant survivorship in response to different herbicides, but we did not include seedling sagebrush in that study. We conducted a greenhouse study where we evaluated herbicide (clethodim, fluazifop, indaziflam, pronamide) application to sagebrush at four timings (preemergence, 4-8 leaves, 10-20 leaves, and year-old transplants). We estimated injury and collected biomass of sagebrush at 23 weeks after planting. Initial ANOVA suggested a herbicide by timing interaction, and we followed up with non-linear regression of sagebrush injury by application timing for each herbicide individually. Zero emergence of sagebrush was observed when indaziflam, pronamide, and clethodim were applied preemergent. Indaziflam injury was 50% or greater at all growth stages except one year-old transplants. Pronamide injury was greatest when applied preemergent and reduced to nearly zero at 10-20 leaves. Clethodim injury was only observed when applied preemergent. Two-way ANOVA of herbicide and sagebrush size indicated no effect on biomass of sagebrush that was alive at harvest. Clethodim and fluazifop are safe on seedling sagebrush but, use of indaziflam and pronamide should be delayed until sagebrush is larger. These herbicides applied at the right size may enhance our ability to restore sagebrush to annual grass-dominated systems.

Fluctuations in Precipitation as a Driver of Response to Invasive Annual Grass Management. Peter W. Maughan*[1], Corey V. Ransom[1], Hailey L. Buell[1], Harry Quicke[2]; [1]Utah State University, Logan, UT, [2]Bayer CropScience, Windsor, CO (050)

Herbicides are critical tools for the prevention and management of weeds in Utah's rangelands. Due to recent, prolonged regional drought, it is important to have a better understanding of how severe drought affects long-term effectiveness of rangeland herbicide applications. Multiple 2017 studies conducted for herbicide control of ventenata (*Ventenata dubia*) and downy brome (*Bromus tectorum*) in rangeland provided an opportunity to measure impact from drought events of the previous 3 years. Data for these studies was collected using point line intercept to quantify invasive grass control and monitor native plant community cover. In the study location with high native plant cover, applications of glyphosate, imazapic, and rimsulfuron contributed to significantly higher populations of weeds post-drought compared to untreated control plots by 103%, 44%, and 34%, respectively. In contrast, indaziflam and indaziflam-inclusive treatments reduced weed populations by 81-92% without significantly damaging native species. Studies conducted on highly degraded sites with weak native populations were less conclusive; severe drought appeared to be the main factor in native population decreases across all plant communities. Results on degraded sites also indicated that native perennial grasses survived drought events better in indaziflam-treated plots compared to the untreated control, with up to 28% more cover. These studies show that environmental conditions play a significant role on the long-term effectiveness of herbicide applications. Indaziflam may be one of the few herbicides that can effectively control invasive annual grasses while allowing native plant cover to remain stable during prolonged drought events.

Targeting Different Life Stages of Dyer's Woad with Various Herbicides and Timings. Erin M. Hettinger*[1], Corey V. Ransom[1], Tom Monaco[2]; [1]Utah State University, Logan, UT, [2]USDA-ARS, Logan, UT (051)

Dyer's woad, *Isatis tinctoria* (Brassicaceae), is an invasive non-native biennial forb present in diverse rangeland systems in Northern Utah and at least nine western states. Field trials were implemented in the fall of 2020 in Northern Utah to identify herbicide combinations and timings that effectively control dyer's woad, with emphasis on understanding how rosette and seedling growth stages are affected. Spring and fall timings of seven herbicide treatments were evaluated in randomized complete block designs. Data were analyzed using multifactorial analysis. At both sites, herbicide treatment significantly impacted the control of dyer's woad for both rosette and seedling counts. Seedling control was significantly greater when indaziflam was used in combination with post emergence treatments, 2,4-D, metsulfuron, and imazapic. However, imazapic alone also offered significant seedling control. Imazapic in spring was more effective at rosette control than in fall, at one site. Inversely, indaziflam treatments had significantly less control of rosettes when applied in the spring than in the fall, however, another season of data is necessary to fully determine rosette control by indaziflam. At both sites, regardless of application timing, the use of indaziflam in conjunction with 2,4-D significantly decreased rosette count compared to 2,4-D alone. Metsulfuron and imazapic alone, or in conjunction with indaziflam, also significantly decreased the number of rosettes. Ultimately, there are effective chemical options for dyer's woad control, however this study does highlight the difficulty in accounting for various life stages when searching for the best control methods.

Comparison of Visual Estimation and Line Point Intercept Vegetation Survey Methods on Annual Grass-invaded Rangelands of Wyoming. Andrea De Stefano*, Beth Fowers, Brian A. Mealor; University of Wyoming, Sheridan, WY (052)

Scientists and natural resource managers require suitable vegetation survey methods to assess the success of rangeland restoration projects. Visual estimation and point intercept methods are commonly used to evaluate vegetation cover. This study compared the performance of one visual (quadrat-based) and two line point intercept (LPI – canopy and basal) methods to assess biodiversity, cover, and to estimate biomass production on sites invaded by introduced annual grasses across Wyoming, USA. Greater species richness and higher Shannon index values were measured in quadrats, while introduced annual and native perennial graminoid cover values were higher in LPI canopy in general. Overall, these outcomes indicate quadrats as the most suitable survey method when biodiversity monitoring is the primary objective, while suggesting LPI canopy when monitoring vegetation cover is prioritized. Finally, our regression models indicated quadrat-based estimates as the most reliable to predict introduced annual and native perennial graminoid biomass.

Chlorsulfuron Ineffective for Controlling Perennial Pepperweed Population in Sierra Valley. Thomas J. Getts*; University of California Cooperative Extension, Susanville, CA (053)

Perennial pepperweed (*Lepidium latifolium*) is a difficult-to-control perennial weed with an extensive root system. In California it's problematic in a wide variety of ecotypes from coastal marshes to riparian areas at higher elevations. Previous research has shown herbicide applications of 2,4-D or chlorsulfuron are most effective when made at the bud stage of growth. While chlorsulfuron is effective for control throughout the intermountain region of California, recent reports of failed applications have come out of Sierra Valley. A trial was implemented in the summer of 2019 on a pepperweed population in Sierra valley to investigate the reports. The trial was laid out in a randomized complete block design with three replications of 3*4.5meter plots where broadcast applications were made with a CO2 pressured backpack sprayer at 185 L ha^{-1} of carrier volume. Applications were made at the bud stage of growth in June of 2019. Treatments consisted of 136 g ai ha^{-1} of chlorsulfuron + NIS, 136 g ai ha^{-1} of chlorsulfuron + MSO, 68 g ai ha^{-1} of chlorsulfuron + MSO, 2,4-D 1463 g ae ha^{-1} + MSO, and an untreated check. Plots were monitored one year after treatment, and 2, 4-D offered 70 percent pepperweed suppression, where chlorsulfuron applications offered less than 40 percent suppression. In June of 2020 the same plots were retreated with the same treatments at the bud stage of growth, and monitored the following year. One year after the second application and two years after the first applications 2, 4-D provided 83 percent Perennial pepperweed control, where chlorsulfuron provided less than 30 percent control. It is still unknown what the root cause of chlorsulfuron's lack of effectiveness is, and this continues to be investigated. Currently, it is hypothesized that unique soil characteristics, or the development of herbicide resistance may be the reason for the inability to control perennial pepperweed with chlorsulfuron.

Identification, Distribution, and Management of Elongated Mustard. Natalie L. Fronk*, Corey V. Ransom; Utah State University, Logan, UT (054)

Elongated mustard is an invasive annual, biennial, or short-lived perennial becoming more common in rangeland and cultivated fields throughout the Western U.S. The purpose of this study was to address a growing need for effective herbicide management options in pasture and rangeland communities. Three studies were established in Southern Idaho in 2020 and one in Northern Utah in 2017. The first 2020 site was established in a perennial grass community and included spring and fall applications of chlorsulfuron, metsulfuron, 2,4-D, imazapic, and indaziflam. 17 months after spring treatment, plant densities were significantly reduced for most treatments. 2,4-D only reduced densities when combined with imazapic, and fall applications of esplanade alone or combined with a spring metsulfuron application also failed to reduce densities. 2020 trials in CRP fields of various legume species included spring and fall applications of imazamox, imazethapyr, imazapic, indaziflam, and glyphosate. In the fall application trial, all treatments except imazamox alone significantly reduced plant densities 8 months after treatment. In the spring application trial, treatments including imazapic at the high rate significantly reduced total plant densities 12 months after treatment. In the 2017 trial all treatments significantly reduced densities the first year, with chlorsulfuron maintaining reduction into the third year, and no significant reduction by any treatments by the fourth year. Results indicate potential use of imazapic, chlorsulfuron, and other herbicide combinations in the management of elongated mustard, with consideration of desirable vegetation and environmental conditions.

Genome Wide Scan for ALS Resistance in *Bromus tectorum*. Mariana F. B. Amaral*, Samuel R. Revolinski, Ian C. Burke, Marija Savic; Washington State University, Pullman, WA (055)

Cheatgrass (*Bromus tectorum* L.) is a problematic weed in wheat cropping system in the drylands of the inland Pacific Northwest (PNW) typified by widespread acetolactate-synthase inhibitor (ALS) herbicide resistance. To identify mechanisms of resistance, 124 genotypes were treated with three sulfosulfuron treatments (1.4, 14 and 142 g ai/a) plus nonionic surfactant at 0.25% v/v in a randomized complete block design with 3 replications, repeated in two different greenhouses. At 7 days after treatment, *B. tectorum* plants were cut for analysis of regrowth. Fresh weight was collected 14 days after treatment. An analysis of variance indicated significant differences between genotypes but not herbicide dose. We observed highly repeatable differences in sulfosulfuron resistance levels between full-sib families. The analysis identified 23 candidate genes for sulfosulfuron resistance, where single nucleotide polymorphisms (SNPs) near these genes explained up to 28% of observed phenotypic variation. Candidate genes included members of the cytochrome P450, ABC-transporter and glycosyltransferase families, representing three of the four characterized gene families involved in non-target site herbicide resistance. Additionally, the analysis revealed two genes encoding serine/threonine-protein phosphatase and a serine/threonine-protein phosphatase catalytic subunit as candidate genes, indicating potential association with non-target site resistance. The finding strongly indicates the role of stress tolerance systems in non-target herbicide resistance, corroborating previous studies. Additional ALS herbicides will be used to study variation in genes associated with resistance in *B. tectorum* among the major ALS herbicide families.

Intact Endothall Translocates to the Roots of Aquatic Plants: Providing Evidence of Systemic Activity. Mirella F. Ortiz*[1], Scott J. Nissen[2], Cody J. Gray[3]; [1]Colorado State University, Fort Collins, CO, [2]Colorado State University, Ft Collins, CO, [3]United Phosphorus, INC., Peyton, CO (056)

Endothall and 2,4-D have been used to control aquatic weeds for more than 60 years, and still there is very little information available about the *in planta* behavior of these herbicides in aquatic weed species. 2,4-D is purportedly a systemic in aquatic plants based almost entirely on its behavior in terrestrial plants. Several recent studies, using radiolabeled 2,4-D and endothall, demonstrated that plants can translocate the radioactivity from shoots to root systems; however, these values were generated by biological sample oxidation and therefore there was no way to determine if the radioactivity in the roots was parent herbicide or a metabolite(s), and the question of the true systemic behavior for 2,4-D or endothall has not been definitively answered. Therefore, the objective of this research was to use multiple analytical methods to answer the question if 2,4-D and endothall are truly systemic in aquatic plants. By using radiolabeled herbicides, it was possible to determine that 68% and 57% of 2,4-D was extractable from shoots and roots, respectively, while 61.7% and 86.0% endothall was extractable from shoots and roots, respectively. About 17% of ^{14}C-2,4-D metabolized into one single unidentified metabolite, while 41% of ^{14}C-endothall was metabolized also into one single unidentified metabolite. The quantities of intact 2,4-D and endothall present in the roots were about 10 times less than the amount of herbicide in the shoots. The intact 2,4-D detected in the shoots was 1.31 µg g^{-1}dry weight (DW) and 0.11 µg g^{-1} DW was detected in the roots. For endothall, 1.08 and 0.12 µg g^{-1} DW was detected in the shoots and roots, respectively. In conclusion, using a combination of ^{14}C-labeled studies and analysis of unlabeled herbicides by LC-MS/MS, we can conclude that both 2,4-D and endothall have similar *in planta* behavior, with about 8-10% of absorbed intact active ingredient translocating to the roots of these aquatic plants. Therefore, endothall should be classified as a systemic herbicide rather than a contact herbicide.

WSWS Project 2. Weeds of Horticultural Crops

Hop Tolerance to Tiafenacil. Ryan J. Hill*, David R. King, Marcelo L. Moretti; Oregon State University, Corvallis, OR (033)

Basal foliage in hops is removed using two or three basal-directed applications of POST herbicides like paraquat or carfentrazone during vegetative growth in mid-summer, primarily to reduce inoculum from powdery and downy mildew. Alternatives for paraquat are needed to cope with increasing regulatory restrictions. We tested tiafenacil weed control efficacy and hop tolerance in four trials between Oregon and Washington 2020 and 2021. Treatments included one or two applications of tiafenacil at the 50 g ai ha^{-1} (expected field rate) and 100 g ai ha^{-1} compared with untreated control and a carfentrazone treatment (35 g ai ha^{-1}) as reference. The first application was made when hop was 0.9 to 1.8 m tall and the second 30 d later. Basal foliage control with tiafenacil was more effective than the carfentrazone, and no signs of crop injury or reduction in plant height were observed throughout the growing seasons. Contrasts combining data from multiple studies showed no effect of application timing, number of applications, or herbicide rate on crop injury or hop fresh weights. However, carfentrazone and tiafenacil reduced cone yield by 20% compared to nontreated. We believe this yield reduction by both herbicides was caused by both early applications of treatments and high variability in hop growth. Tiafenacil seems to be a viable alternative for paraquat as it provides better basal shoot control than carfentrazone and similar crop tolerance. However, further work must be done to confirm crop tolerance while preserving crop health and pathogen suppression.

Performance of Florpyrauxifen-Benzyl in High Bush Blueberry. David R. King*, Ryan J. Hill, Marcelo L. Moretti; Oregon State University, Corvallis, OR (034)

Florpyrauxifen-benzyl is a synthetic auxin herbicide with postemergence activity in broadleaves, grasses, and sedges. The tolerance of blueberry to florpyrauxifen-benzyl has not been evaluated previously. Field experiments evaluated florpyrauxifen weed control and crop tolerance in "Duke" or "Elliot" blueberries in Corvallis, OR in 2021. Treatments were sprayed as a basal-directed treatment at petal fall (A), 30 d later (B), or in both timings (A followed by B) using a shielded or unshielded sprayer. Florpyrauxifen-benzyl at 30 and 60 g ai ha^{-1} caused up to 30% injury on blueberry basal shoots directly exposed to treatments at seven days after treatment (7 DAT-A). Applications made 30 d after petal fall caused less damage (<3%) in both cultivars. No treatment effect was recorded on shoot size, yield, or average berry size. Florpyrauxifen-benzyl provided up to 60% control at 14 DAT-A compared to 30% or less at 14 DAT-B. Weeds, mostly crabgrass, were larger at the B application and likely reduced efficacy. These data show that blueberry tolerates basal application of Florpyrauxifen-benzyl when foliage is not exposed. Applications done after petal fall are less likely to cause damage. This work will continue in 2022.

Hazelnut Tolerance to Pyroxasulfone, Pronamide, and S-metolachlor. Rafael M. Pedroso*[1], Marcelo L. Moretti[2]; [1]Oregon State University, Philomath, OR, [2]Oregon State University, Corvallis, OR (035)

Owing to the limited number of labeled pre-emergent herbicides (PRE), newly-planted hazelnut (*Corylus avellana* L.) orchards in Oregon are more frequently treated with post-emergent herbicides such as glufosinate and glyphosate. As a result, herbicide-resistant *Italian ryegrass* populations have evolved under recurrent selection of a single mode of action. Field experiments were conducted in 2019 and 2020 in Amity, Canby, and Corvallis in Oregon to evaluate the tolerance of newly-planted hazelnuts to basal banded applications of pyroxasulfone, pronamide, and S-metolachlor at three increasing rates. These are soil-applied herbicides with the potential to control broadleaf and grassy weeds including populations resistant to group 1, 2, and 9 herbicides. Another study evaluated weed control with individual or tank-mixed applications of PRE in a newly-planted hazelnut orchard in Aurora, OR. Application rates of PRE ranged from 73 g ai ha^{-1} (indaziflam) to 4,500 g ai ha^{-1} (simazine), and all treatments were compared to pendimethalin (4,260 g ai ha^{-1}) as a standard soil-applied herbicide. Visual evaluations of weed control and hazelnut injury were made at regular intervals following applications. Weed control efficacy was also inferred from ground coverage and dry aboveground biomass data, whereas tree biometric parameters (internode length, trunk cross-sectional area, and canopy volume) and chlorophyll content measurements were taken to further evaluated crop safety. Minimal to no injury levels were observed in all studies. Lack of differences between treatment means in all tree biometric and chlorophyll content measurements further support that newly-planted hazelnuts tolerate individual applications of pronamide, pyroxasulfone, and S-metolachlor at rates up to 8,300, 950, and 4,160 g ai ha^{-1}, respectively, corresponding to 3x their use rates in labeled crops. Treating newly-planted hazelnut orchards with pyroxasulfone (238 g ai ha^{-1}) or pronamide (2,310 g ai ha^{-1}) either individually or mixed with simazine (4,500 g ai ha^{-1}), pendimethalin (4,260 g ai ha^{-1}), or isoxaben (1,130 g ai ha^{-1}) further demonstrated their safety of use. Prickly lettuce control was variable. However, Italian ryegrass control following applications ranged 67-100% at the end of the trial with no differences among treatments. A single application of indaziflam (73 g ai ha^{-1}) was also shown to be safe while allowing for excellent Italian ryegrass and prickly lettuce control. Treating newly-planted hazelnut orchards with indaziflam, pyroxasulfone, pronamide, and S-metolachlor could thus be regarded as a safe means for controlling Italian ryegrass while decreasing herbicide-resistance development likelihood under recurrent selection of a single mode of action.

European Hazelnuts Tolerance to Clopyralid and Quinclorac Basal-Directed Applications. Rafael M. Pedroso*[1], Marcelo L. Moretti[2]; [1]Oregon State University, Philomath, OR, [2]Oregon State University, Corvallis, OR (036)

Field studies were conducted to determine European hazelnut tolerance to quinclorac and clopyralid for control of field bindweed and Canada thistle at three commercial hazelnut orchards in Oregon's Willamette Valley. Hazelnut cultivars included 'Jefferson', 'Wepster', and 'McDonald'. Clopyralid at 278, 547, and 1,090 g ai ha^{-1}, and quinclorac at 420, 840, and 1,680 g ai ha^{-1} were applied once a year as basal-directed applications to trees that were one-three-years-old. Treatments were imposed in the early spring of 2019 and reapplied in 2020. In both years, treatments covered hazelnuts suckers. Clopyralid and quinclorac injury was consistently between 0 and 13% and not different from nontreated control plants ($p>0.05$) between 14 and 455 d after initial treatment. Similarly, there was no treatment effect in plant canopy index, leaf chlorophyll content, trunk cross-sectional area, internode length, or yield across treatments, even at the highest rates of clopyralid and quinclorac. In separate efficacy studies, clopyralid (278 g ai ha^{-1}) resulted in 68% control of Canada thistle, and control was not different when clopyralid was mixed with carfentrazone (278 + 35 g ha^{-1}) or glufosinate (278 + 1,148 g ha^{-1}). All clopyralid-containing herbicide treatments suppressed field bindweed (<40%) even when mixed with carfentrazone or glufosinate. Quinclorac (420 g ai ha^{-1}) alone provided 80% control of field bindweed and 93 and 98% control when combined with rimsulfuron (35 g ai ha^{-1}) or carfentrazone (35 g ai ha^{-1}), respectively. Still, all treatments resulted in similar field bindweed biomass. The results presented herein confirm that clopyralid and quinclorac are effective tools to manage Canada thistle and field bindweed in hazelnut orchards and that hazelnuts tolerate clopyralid and quinclorac at rates equivalent to 4-fold commercial use rates, with no adverse effects on plant growth and yield.

Use of Preemergence Herbicides in California Orchard and Vineyard Systems. Andres Contreras*, Brad Hanson; University of California, Davis, CA (037)

Preemergence herbicides are commonly used in many orchard and vineyard production systems. As new herbicides are evaluated for potential registration in California orchard and vineyard crops, crop safety and performance data are needed. Two formulations of a group 15 herbicide (inhibitors of very long chain fatty acids) were evaluated in several field trials. Exp-82 (a suspension concentrate) and Exp-94 (a water dispersible granule) are currently used as preemergence herbicides for use in corn, soybean, and cotton in Midwestern states of the United States. Orchard and vineyard crop safety and weed control efficacy of Exp-82, Exp-94, and comparable commercial standards including flumioxazin, pendimethalin, and rimsulfuron were evaluated in a series of bare ground, vineyard, mature almond orchard, and 2-year-old almond orchard trials. Trials were initiated in fall of 2020 and spring of 2021; evaluations were performed visually and carried out up to 150 days after application. Exp-82 and Exp-94 performed similarly to commercial standards in all trials with a range of 70 to 95% control of winter- and spring-emerging weeds. No significant difference was found in weed control among treatments in any of the trials. No crop injury was observed in any trials, indicating a potential as an alternative herbicide for use in California vineyard and orchard systems. Similar research will continue through 2022 to evaluate additional weed species and crop safety with repeated treatments of the experimental herbicide and commercial standards.

Greenhouse Studies Comparing Imazosulfuron Against Commonly Used Herbicides for Yellow Nutsedge Control in Chile Pepper. Andea Nunez, Edward Morris, Brian J. Schutte*; New Mexico State University, Las Cruces, NM (038)

Although New Mexico chile pepper growers have the opportunity to use imazosulfuron for controlling yellow nutsedge (*Cyperus esculentus*), imazosulfuron is rarely applied in chile pepper in New Mexico. To familiarize growers and consultants with the benefits and limitations of imazosulfuron, we conducted greenhouse studies that compared imazosulfuron against conventional herbicides for controlling yellow nutsedge in chile pepper. Specifically, we conducted greenhouse studies framed by the following two objectives: 1) compare imazosulfuron, halosulfuron-methyl, and S-metolachlor for capacities to prevent emergence of yellow nutsedge infestations that differ in tuber density (herein, "pre-emergence control study"), and 2) compare imazosulfuron, halosulfuron-methyl, and glyphosate for capacities to control yellow nutsedge plants that differ in size at the time of treatment (herein, "post-emergence control study"). For the pre-emergence control study, treatments were factorial combinations of yellow nutsedge infestation density (equivalent to 100, 500, 1000, 1500 tubers m^{-2}) and herbicide (imazosulfuron at 335 g ai ha^{-1}, halosulfuron-methyl at 53 g ai ha^{-1}, S-metolachlor at 1419 g ai ha^{-1}). For the post-emergence control study, treatments were factorial combinations of yellow nutsedge size at treatment (8, 16, 25 cm plant height), herbicide (imazosulfuron, halosulfuron-methyl, glyphosate), and herbicide application rate (low, high). Low application rates were minimum label rates for chile pepper (imazosulfuron at 168 g ai ha^{-1}, halosulfuron-methyl at 26 g ai ha^{-1}) or minimum label rates for yellow nutsedge control (glyphosate at 794 g ae ha^{-1}). High application rates were maximum label rates for chile pepper (imazosulfuron at 335 g ai ha^{-1}, halosulfuron-methyl at 53 g ai ha^{-1}) or maximum label rates for yellow nutsedge control (glyphosate at 2395 g ae ha^{-1}). All post-emergence herbicide solutions included label-recommended adjuvants. Results indicated that imazosulfuron, halosulfuron-methyl, and S-metolachlor each reduced yellow nutsedge emergence compared to the non-treated control. Imazosulfuron and S-metolachlor completely prevented emergence for the duration of the study (42 d). Yellow nutsedge shoots were detected in higher density treatments (1000, 1500 tubers m^{-2}) at 35 d after halosulfuron-methyl applications. For the post-emergence control study, imazosulfuron, halosulfuron-methyl, and glyphosate each reduced yellow nutsedge dry weight and tuber quantity compared to the non-treated control. Yellow nutsedge dry weight at 28 d after treatment (DAT) was affected by both plant size at treatment and herbicide application rate, but, yellow nutsedge dry weight was not affected by herbicide. Yellow nutsedge tuber quantity at 28 DAT was affected by interactions among plant size at treatment, herbicide, and herbicide application rate. In general, halosulfuron-methyl at low and high rates best suppressed the increase in tuber quantity that coincided with increased plant size at treatment. The combined results from our greenhouse studies suggest that imazosulfuron provides greater pre-emergence control of yellow nutsedge than halosulfuron-methyl. If yellow nutsedge plants are large (> 16 cm height) at the time of treatment, halosulfuron-methyl may provide greater control than imazosulfuron. These conclusions will be tested with field studies conducted in the context of New Mexico chile production.

Hazelnut Crop Safety Using Electric Weed Control. James R. Wirth*[1], Rafael M. Pedroso[2], Marcelo L. Moretti[1]; [1]Oregon State University, Corvallis, OR, [2]Oregon State University, Philomath, OR (039)

Electric weed control is a novel technology that could mitigate herbicide-resistance selection pressure and serve as an alternative to mowing and soil tillage in tree crops. This study evaluates whether electric weed control affects the growth of a juvenile stand of hazelnut trees. Electric current (EC) was generated by a commercial unit EH-30 Thor. The equipment has a PTO-driven generator and transformer of 24 KW producing between 5 and 12 kV of current applied by two 0.6 by 0.5 m wide applicators mounted on the front of the tractor. The applicators have two sets of electrodes, metal strips about 0.3 m long contact the plant foliage or soil. A study was designed as a two-factor factorial organized as a randomized complete block design planted in 2020 at OSU research farm. The first factor is hazelnut variety Yamhill and McDonald, and the second factor is the floor management treatment. Treatments included EC applied 0.4, and 2 km h-1 applied w/ or without sucker removal. A weed-free check and soil cultivation (side harrow) were included as references. Treatments were applied four times since planting. Tree trunk cross-sectional for Yamhill and McDonald were 13.9 and 15.8 mm2 in 2021 and were not affected by treatments. A significant interaction of variety and treatment was noted for canopy volume and leaf weight; however, treatment responses did not consistently affect varieties and treatments. The research presented here is the first year of a multi-year study.

Cover Crops for Weed Suppression in Irrigated Crops of the Arid Southwest. Erik A. Lehnhoff*[1], Prashasti Agarwal[2], Robert L. Steiner[1], Brian J. Schutte[1]; [1]New Mexico State University, Las Cruces, NM, [2]Virginia Polytechnical, Blacksburg, VA (040)

Cover crops (CC) may facilitate weed management by inhibiting weed seed germination and seedling emergence and suppressing weed growth within the cash crop. In New Mexico, with scarce winter precipitation and limited irrigation water, producing sufficient CC biomass for effective weed suppression while conserving water challenges sustainability. We assessed the water requirement to produce a CC with enough biomass for weed suppression benefits during cash crop growth at two locations in New Mexico. Three winter CC species, barley, Austrian winter pea and mustard, grown singly and in a three-way mix, under three differential irrigation treatments (one, two or three irrigations after emergence) were evaluated for their weed-suppressive potential. Maize was planted as a cash crop four weeks after CC termination. Number of irrigations had no effect on the CC and weed biomass production. All plots with CCs had lower weed density prior to maize planting compared with fallow. Barley and the three-way mix reduced weed density by 56–96% and 68–95%, respectively. All CC treatments had lower weed biomass at the end of critical period for weed control in maize compared with fallow. Weed biomass at maize harvest did not differ between treatments. The maize yield was consistently higher in conventionally managed, weed-free subplots, than in unsprayed weedy subplots, suggesting that CCs did not suppress weeds throughout the maize growing season. Except for barley, CCs did not cause reductions in maize yield compared with fallow. The study suggested that with adequate winter precipitation, weed-suppressive winter cover crop stands can be produced with just one irrigation at seeding and one supplemental irrigation, making them a viable option in water-limited agroecosystems.

Effect of Adjuvant and Tankmix on Garlic Tolerance to Bicyclopyrone. Ed Peachey*[1], Stephen M. Schraer[2], Andrew Nagy[1]; [1]Oregon State University, Corvallis, OR, [2]Syngenta Crop Protection, Meridian, ID (041)

Garlic production requires 10 or more months in the field, from early fall to mid-summer, and weed control is a challenge. Bicyclopyrone is an HPPD herbicide with potential to improve weed control options in garlic. Experiments were conducted in 2020 and 2021 in commercial garlic fields of western OR. Herbicides were applied to plots in a RCBD design with 4 reps Post Plant Surface (PPS), or POST at 2 to 4 leaves. Bicyclopyrone was applied with and without adjuvants (AMS) or as a tankmix with dimethenamid-P or pendimethalin. A broadcast application of flumioxazin was applied PRE to all bicyclopyrone treatments. Bicyclopyrone caused little to no injury at 50 g ai ha^{-1}, but injured garlic and reduced yield at 100 g ai ha^{-1} (2x rate simulating overlaps). Adding AMS to bicyclopyrone treatments increased injury, as did tankmixing with dimethenamid-P herbicide. Treatments with AMS reduced growth by as much as 29% when bicyclopyrone was applied at 100 g ai ha^{-1}. The smallest yields were with treatments that included bicyclopyrone with either AMS or the higher rate of 100 g ai ha^{-1}. Bicyclopyrone has not yet received EPA approval for use in garlic.

Liberty Link Sweet Corn Tolerance to Sinate and Other Herbicides. Ed Peachey*[1], Richard K. Zollinger[2], Andrew Nagy[1]; [1]Oregon State University, Corvallis, OR, [2]Amvac Chemical Company, Spokane Valley, WA (042)

Sweet corn tolerance to Sinate herbicide (glufosinate + topramezone) was evaluated in western OR on a Chehalis silty clay loam soil in 2021. Two LibertyLink varieties of sweet corn (Aspire and Milky Way) were planted on 31-May at approximately 64,000 seeds ha^{-1} with 2 rows of each variety per plot in a RCB design. Sinate treatments were applied with DG11002 nozzles at 140 L ha^{-1}, 207 kPa, and at 1.5 and 3.0 l ha^{-1}. Crop injury was evaluated on 28-Jun, 2-Jul, 9-Jul, and 16-Jul. Weed control was rated on 2, 9, 16, and 27-Jul. Primary species present were pigweed (AMARE) and common purslane (POROL). Sweet corn ears were harvested from 3 m of one middle row for each variety on 3-Sept at 75% kernel moisture. Injury from Sinate was greater when applied at V2 than at V6 (<30 cm ht.). Crop injury also was more frequent when Sinate was applied as a tank mix with s-metolachlor, and noted initially when tankmixed with atrazine. 'Milky Way' appeared to be more sensitive to Sinate than 'Aspire'. Injury dissipated similarly for the two varieties based on Repeated Measures Analysis of injury over the four evaluation times (DF3,261; F=1.63, P= 0.20). Crop injury ratings on 9 and 16-Jul were negatively correlated with yield. We noted that a few corn plants (approx. 4 in the entire planting) were intolerant to glufosinate. Weed control was exceptional for Sinate treatments that included s-metolachlor PRE. Treatments with glufosinate only did not sufficiently control weeds and reduced yield by more than 4.5 MT ha-1.

Pendimethalin Applications to Seeded Onion: Grower Field or University Ground - Does it Matter? Avery Shikanai, Harlene M. Hatterman-Valenti*; North Dakota State University, Fargo, ND (043)

Weed control in seeded onion (*Allium cepa* L.) is challenging due to slow crop emergence and poor competitive ability. To preserve onion yields, growers typically depend on multiple applications of residual herbicides. Pendimethalin has been promising in university research, but the domain of inference is ill-defined. Implicitly, the assumption is that field and herbicide do not interact, and that recommendations can be extrapolated to surrounding areas. However, fields used for weed science research can differ from grower fields in cultural practices, weed populations, and scale. To address these concerns, we evaluated herbicide programs with varying pendimethalin rates (0, 399, 799, 1598 g ai ha^{-1}) and application timings (PRE, loop, 1-, and 3-leaf stage) at either a grower's field (GF) or a research and extension center (REC) over two years. Weed control was similar across locations despite differences in site, weather, and other cultural methods. However, in 2020 at GF, pendimethalin applied at the loop stage provided poor control of common lambsquarters (*Chenopodium album* L.) despite excellent performance at REC. Likewise, any rate of pendimethalin applied PRE provided unacceptable control of redroot pigweed (*Amaranthus retroflexus* L.) at REC in 2021, despite excellent performance at GF. Despite reduced weed control, there were no statistically significant differences in yield. Taken together, these data show that pendimethalin can be successfully incorporated into an integrated weed management plan for onion. However, site- and year-specific weed control failures underscore the importance of multi-environment trials.

WSWS Project 3. Weeds of Agronomic Crops

Burndown Herbicide Options for Dormant Alfalfa. Earl Creech*, Corey V. Ransom; Utah State University, Logan, UT (001)

Abstract not available

Control of Acetolactate Synthase (ALS)-resistant Palmer Amaranth with Sequential PRE/POST Applications of dimethenamid-P in Dry Bean. Joshua W.A. Miranda*[1], Amit J. Jhala[2], Jeff Bradshaw[3], Nevin Lawrence[3]; [1]Oregon State University, Corvallis, OR, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]University of Nebraska-Lincoln, Scottsbluff, NE (002)

Palmer amaranth has become more prevalent in Western Nebraska, a major dry bean-producing region, where ALS-resistant biotypes are widespread in the region. There are limited effective

POST herbicides for ALS-resistant Palmer amaranth control in dry bean. A field study was conducted in 2019, 2020, and 2021 in Scottsbluff, NE to evaluate the efficacy of dimethenamid-*P* in a sequential PRE *fb* (followed by) POST program, where the POST application was made at either V1 or V3, for control of ALS-resistant Palmer amaranth in dry bean. PRE applications of dimethenamid-*P* were tank-mixed with pendimethalin for all herbicide treatments. Pendimethalin + dimethenamid-*P*applied PRE-alone provided effective season-long Palmer amaranth control in 2020. Pendimethalin + dimethenamid-*P*fb dimethenamid-*P* at V3 provided effective season-long Palmer amaranth control in 2020 and 2021. Pendimethalin + dimethenamid-*P* fb dimethenamid-*P* at V1 provided effective season-long Palmer amaranth control in all three years. Palmer amaranth biomass was reduced 95-99% and 96-98% when dimethenamid-*P* was applied POST at V1 and V3, respectively, following a PRE application of pendimethalin + dimethenamid-*P*, in 2020 and 2021. Palmer amaranth emergence timing is highly depended on environmental conditions and the timing of Palmer amaranth emergence was inconsistent in all three years. Dimethenamid-*P* at V1 following a PRE application of pendimethalin + dimethenamid-*P*was the only timing that was effective in all three years. The use of dimethenamid-*P* in a sequential PRE *fb* POST program is the only remaining effective option to control ALS-resistant Palmer amaranth in dry bean.

Blackeye Bean Selectivity to Broadleaf POST-applied Herbicides in CA. Jose Luiz Carvalho de Souza Dias*[1], Rachel Long[2]; [1]University of Arizona, Maricopa, AZ, [2]University of California Cooperative and Extension, Davis, CA (003)

Effective postemergence (POST) control of broadleaf weeds is a major concern in high yielding blackeye beans (*Vigna unguiculata*) fields in California due to the limited number of selective broadleaf herbicide options. Field experiments were conducted in 2021 to determine the tolerance of blackeye beans (CB5) to POST-applied broadleaf herbicides used in other dry bean species in California, or other legume crops in the US. The effects of herbicide treatments on blackeye beans visual estimates of injury (%) and yield (kg ha^{-1}) were investigated near Parlier, CA on a Hanford fine sandy loam (0.75% OM, 13% clay); and near Davis, CA on a Yolo silt loam (2.2% OM, 26% clay). Herbicide treatments included both systemic and contact herbicides and consisted of: bentazon (560 g ai ha^{-1}), imazamox (35 g ai ha^{-1}), imazethapyr (105 g ai ha^{-1}), pyridate (438 g ai ha^{-1}), acifluorfen (280 g ai ha^{-1}), reflex (211 g ai ha^{-1}), 2,4-DB (245 g ai ha^{-1}), bromoxynil (420 g ai ha^{-1}), sulfentrazone (140 g ai ha^{-1}), bentazon + imazamox (560 + 35 g ai ha^{-1}), bentazon + imazethapyr (560 + 105 g ai ha^{-1}), bentazon + acifluorfen (560 + 280 g ai ha^{-1}), and bentazon + sulfentrazone (560 + 140 g ai ha^{-1}). A weed-free (hand weeded) and weedy (untreated control) treatments were also included. All herbicide treatments contained AMS (0.1 % v/v/) + NIS (0.25% v/v) and were applied when blackeye benas were 10-15 cm tall and exhibited 4-7 true leaves. Blackeye bean injury (%) was affected by herbicide treatments at all evaluation timings (1, 2 and 4 wks after treatment; WAT) at both locations ($P < 0.001$). However, injury was transient and only 2,4-DB resulted in more than 5% injury by 4 WAT at Davis (70% injury). Although injury was more severe at Kearney (likely due to the sandier soil), symptoms were also transient and only pyridate, 2,4-DB, sulfentrazone and bentazon + acifluorfen resulted in more than 20% injury (23, 78, 29, and 23%; respectively) by 4 WAT. Although blackeye bean yield (kg ha^{-1}) differed between locations ($P < 0.05$); there were no differences among treatments ($P > 0.05$); and only 2,4-DB (44% reduction) resulted in more than 5% yield reduction compared to the weed-free (hand-weeded) treatment. Results from this study indicate blackeye beans may be tolerant to over-the-top applications of many POST-applied broadleaf herbicides currently registered in CA for use in Lima and common beans (bentazon), or in other legume crops such as alfalfa (imazamox and imazethapyr). However, more research is needed to better understand the degree to which edaphoclimatic factors impact blackeye bean sensitivity to these treatments. Other potential barriers that need to be taken into consideration are the limitations in terms of crop rotation intervals and ground water protection restrictions.

Pinto Bean Response to Preplant Dicamba. Greg Endres*[1], Joseph T. Ikley[2], Brian Jenks[3], Mike Ostlie[1], Nathan H. Haugrud[2]; [1]North Dakota State University, Carrington, ND, [2]North Dakota State University, Fargo, ND, [3]North Dakota State University, Minot, ND (004)

Preplant (PP) soil-applied dicamba is a useful, low-cost tool for burndown of early-season broadleaf weeds and may provide short-term residual weed control. Dicamba label restrictions include requiring 1 inch of rainfall after application and 120-day delay before planting dry bean to minimize potential crop injury. A field study was conducted in 2021 by North Dakota State University to evaluate pinto bean response to a low-dose rate of PP dicamba based on planting interval and precipitation after application. Dryland trials were conducted at Prosper and Minot, and at a center-pivot irrigated site near Carrington. Dicamba at 0.12 lb ai/A was applied during May 7-17. Pinto bean was planted 2-7 days and 16-20 days following application of dicamba. Rainfall ranged from 0-0.8 inch between dicamba application and first planting dates, and total water as rain and irrigation was 0.74, 0.96 and 2.16 inches at Prosper, Minot and Carrington, respectively, at the second planting dates. Visually evaluated plant response (biomass and stand reduction) ranged from 9-28% at Carrington, 50-65% at Prosper and 91-93% at Minot with the first planting dates. Plant injury associated with the second planting dates ranged from $\leq$7% at Carrington, 24-40% at Minot, and 30-58% at Prosper. Seed yield was measured only at Carrington, and was similar (29.9-31.3 cwt/A) among untreated checks and dicamba treatments. In summary, dicamba caused severe visual injury and stand reduction at the dryland sites, while the irrigated site with higher precipitation showed low to moderate injury, but seed yield was not impacted. The study will be repeated in 2022.

Split-Residual Herbicide Treatments for Late-Season Weed Control in Dry Bean. Tyler C. Hicks*[1], Andrew R. Kniss[2], Jim J. Heitholt[2]; [1]University of Wyoming, Fort Collins, CO, [2]University of Wyoming, Laramie, WY (005)

Late-season weeds in dry edible bean production present harvest challenges and also increase seed-cleaning costs after harvest. Late-season weeds are a problem in the dry bean crop because the residual activity of standard preemergence (PRE) herbicides dissipates too early in the season, and while postemergence (POST) herbicides control emerged weeds, they typically do not provide soil residual activity for weeds that emerge after the POST application. The objective of this research was to test multiple PRE and POST herbicide combinations to determine whether efficacy of soil residual herbicides could be increased by splitting the herbicide treatment into PRE plus POST applications. A field study was conducted in 2021 near Powell, Wyoming. The study was a randomized complete block design with four replications of 13 treatments. The treatments included PRE applications of EPTC + ethalfluralin, pendimethalin, pendimethalin + halosulfuron, and pendimethalin + dimethenamid-P. Post treatments applied at the 2-3 trifoliolate stage included imazimox + bentazon, halosulfuron, dimethenamid-P, and imazimox + bentazon + dimethenamid-P. Weed control was evaluated by species multiple times throughout the growing season. The split-residual application method improved control of common lambsquarters (*Chenopodium album*), but did not improve hairy nightshade (*Solanum physalifolium*) control. Bentazon + imazamox applied POST was much more important for adequate weed control and bean yield then how the residual herbicide was applied. This split residual application approach may have some promise, but more research is needed.

Control of Downy Brome and Feral Rye with Aggressor (Quizalofop-p-ethyl) in CoAXium Wheat. Judit Barroso*[1], Jennifer A. Gourlie[1], Victor H. Ribeiro[2]; [1]Oregon State University, Adams, OR, [2]Oregon State University, Corvallis, OR (006)

Downy brome (DB, *Bromus tectorum* L.) and feral rye (FR, *Secale cereale* L.) are two predominant winter annual grasses in wheat cropping systems of the semi-arid region of Pacific Northwest that are hard to control due to their resistance to group 2 herbicides (ALS inhibitors). We studied the weed control and crop safety of Aggressor herbicide (quizalofop (ACCase inhibitor)) in CoAXium Wheat in ten experiments across multiple locations in northeastern Oregon for five years. The experiments were randomized complete block designs with four replications. One-way analysis of variance was conducted with different treatments as the fixed factor and replication as the random factor. Studied treatments included different Aggressor rates (8, 10, 12, and 14 fl oz/ac), different adjuvants and N fertilizers in the tank with Aggressor, and application times. Results indicated that the control of DB and FR was very good. In general, the control was higher than 80%, and many times close to 99%, particularly with low infestations. We also observed that increasing the Aggressor rate above 8 fl oz/ac did not increase DB control, but it increased FR control. In heavy infestations, a fall application was needed to prevent yield loss. Benefits were not observed with the application of an N fertilizer in the tank with Aggressor. This study shows very promising results to reduce infestations of these two species in the region but weed resistance best management practices and CoAXium-Aggressor stewardship adoption will be critical to slow the development of resistant weed biotypes.

Understanding Water Utilization in Irrigated Spring Wheat and by Inter-seeded Cover Crop, Dynamite Red Clover. Dani Thiemann*[1], Corey V. Ransom[2], Earl Creech[2]; [1]Utah State University, Nibley, UT, [2]Utah State University, Logan, UT (007)

Competition exerted by weeds for water resources impedes the quality and quantity of irrigated crops. Integrated weed management (IWM) tactics, including using cover crops for competitive suppression of weeds can be an effective management tool. However, producers have concerns over the increased demand that cover crops may place on water resources. The objective of this research is to identify water use dynamics in the field and how competition over water influences the suppressive ability of cover crops. In a two-year field study, water uptake by wheat and kochia [*Bassia scoparia* (L.) A.J. Scott] at five soil depths were compared to those with a dynamite red clover [*Trifolium pratense*] cover crop using isotope analysis. A greenhouse replacement series competition study was used to compare the performance of kochia and dynamite red clover under varied levels of water availability. As expected, wheat and kochia accessed water from shallower depths early in the season and from deeper depths later. Cover crop presence in the field did not influence the uptake of water by wheat. This may be due to clovers later germination and poor establishment. In the greenhouse, clover was influenced by water availability but not by interspecific competition with kochia. For kochia, both water availability and population density had an influence. Intraspecific competition of kochia had more influence than the interspecific competition, driving reductions in individual biomass accumulation with increased water availability. These findings have helped in better understanding how competition over water resources is influencing competitive dynamics.

Timing of Cover Crop Termination Effect on Sugarbeet Yield. Jenna Meeks*; University of Wyoming, Torrington, WY (008)

Proper management of cover crop biomass production can result in weed suppression while maintaining optimal sugarbeet yield. Early planting, high seeding rate, and late termination of the cover crop results in biomass production which can suppress weeds. Field studies were conducted at four sites (Lingle and Powell, WY; Scottsbluff, NE; Huntley, MT) in 2021 to evaluate the effect of cover crop termination time on sugarbeet yield. Cover crop (winter wheat) was planted in March and terminated with glyphosate at seven timings ranging from 7 days before to 30 days after sugarbeet planting. Plots were sprayed with glyphosate as needed the rest of the growing season to minimize yield impacts from weeds. Data from the Lingle site was excluded due to substantial presence of glyphosate-resistant kochia impacting sugarbeet yield. At the remaining three sites, sugarbeet yield followed a parabolic response with peak sugarbeet yield observed when the cover crop was terminated at 6 days before sugarbeet planting. However, sugarbeet yield remained relatively stable, even if the cover crop was terminated >20 d after sugarbeet planting. The relative lack of sugarbeet yield response to late cover crop termination timing is due to low biomass production of the cover crop. At the time of sugarbeet planting, the cover crop produced 158 kg/ha of biomass at Scottsbluff, and =11 kg/ha at Huntley and Powell. This level of biomass production is unlikely to suppress weeds or to have a substantive negative impact on the sugarbeet crop, explaining the relatively flat sugarbeet yield curves we observed.

Barley Cover Crop Termination Date Affects Weed Suppression in Chile Peppers. Kylie M. Gallegos*; New Mexico State University, Las Cruces, NM (009)

Hordeum vulgare (barley) produces allelopathic chemicals and abundant biomass which may reduce seed germination and seedling emergence, making barley a good cover crop (CC) choice to improve weed management. Timing of barley CC termination and soil incorporation is important as its secondary metabolites and biomass are not selective and can inhibit both weed and crop seed germination. To determine barley CC termination date that provides maximum weed suppression while not inhibiting *Capsicsum anuum* (chile pepper) germination we investigated three barley CC termination dates with a pre-emergent herbicide, Devrinol, applied at three rates in chile peppers grown in southern New Mexico. The two latest termination dates produced the most biomass (P= <0.0001), but this did not translate to improved weed suppression. Regardless of herbicide rate, weed seedling counts and hoeing times demonstrated that later termination dates provided less weed control. Unexpected fallow plots had the lowest weed counts and fastest hoeing times. Chile emergence was highest in fallow plots followed by plots with later termination dates and was lowest in plots that were terminated earliest. Chile yields in fallow plots were highest followed by late termination plots. It is possible that high amounts of CC residues in soils impeded the ability of the soil incorporated herbicide, increasing weed germination in late termination plots. Earlier termination of barley CC may provide more weed suppression but may also inhibit chile pepper germination. Future trials are planned to investigate how CC biomass and herbicide interact to affect weed seedling emergence.

Structured PRE and POST Programs for Crop Tolerance and Weed Control in Industrial Hemp. Stevan Knezevic*; University of Nebraska-Lincoln, Concord, NE (010)

Nebraska legalized industrial hemp in 2019, therefore, we conducted study at Agronomy Farm in Mead (NE), with the objective to test hemp tolerance to several PRE and POST herbicides commonly used in corn or soybean. The PRE treatments were applied one day after hemp planting, compared to POST treatments at the 20-25cm of hemp height. Hemp injury ratings were conducted at 15, 21, and 28 days after treatment (DAT) in PRE and 6,13 and 20 DAT for POST herbicides, utilizing the scale from 0-100 (0=no injury; 100=dead plant). No hemp injury was evident with 30 g ai/ha of Sharpen (saflufenacil) or 70 g ai/ha of Stinger (clopyralid) applied PRE. Temporary hemp injury, which lasted first two weeks, was evident in multiple plots, in the form of leaf yellowing. For example, Dual II Magnum (S-metolachlor @ 1788 g ai/ha) or Hornet (flumetsulam + clopyralid @ 96g ai/ha), or Python (flumetsulam @ 25.9 g ai/ha) applied PRE caused 8-20% visual injury at 15 DAT, however by 21 DAT most of those injuries were reduced to about 5%, and by 28 DAT to zero, indicating hemp recovery. From POST products, 52.4 g ai/ha of Assure II (quizalofop), or 1788g ai/ha of Dual II-Magnum or 157 g ae/ha of Stinger (clopyralid) were the safest causing temporary injury of up to 10%. Severe hemp injury (50-100%) was caused by POST application of 96 g ai/ha of Hornet and 420.3 g ae/ha of Moxy 2E (bromoxynil) applied POST, thus they should not be used.

Exploratory PRE and POST Treatments for Crop Tolerance in Industrial Hemp. Stevan Knezevic*; University of Nebraska-Lincoln, Concord, NE (011)

Hemp tolerance to PRE and POST herbicides from groups 2, 3, 4, 5, 6, 13, 14, 15, and 27 was tested at Agronomy Farm near Mead. PREs were applied one day after planting (DAT) and POSTs to 25-50 cm tall hemp. Visual ratings were taken at 15, 28, and 49 DAT for the PRE and 6, 13, and 20 DAT for the POST utilizing the 0-100 scale, where 0 = no injury to 100 = complete death. Visual injury levels ranged from no injury (0%) to visible injury (<30%), and in several cases, severe injury or death (>45%). PRE applications of halosulfuron, pendimethalin, flumioxazin, and sulfentrazone showed promise with 28 DAT ratings below 5%, while clomazone and isoxaflutole did cause complete death of the hemp plant. For POST applications, injury ratings varied greatly in each herbicide classification group except group 2, which exhibited unacceptable injury for all products tested. For group 4 herbicides, clopyralid and quinclorac displayed initial injury, then recovered, while fluroxypyr was extremely phytotoxic. Interestingly, the 2+4 combination herbicide flumetsulam+clopyralid was injurious to hemp. In group 6 herbicides, bentazon was damaging while bromoxynil could possibly be a rescue treatment, if some injury could be tolerated. Group 14 stand-alone herbicides point to flumiclorac's potential, while fomesafen and lactofen caused 45% and 37% injury, respectively, at 20 DAT. Group 14+15 combination herbicides also have potential as a rescue treatment, and to provide residual, however it is not clear why fomesafen+acetochlor did not cause as much injury as fomesafen applied alone.

Industrial Hemp Biomass Negatively Affected by Herbicide Drift from Corn and Soybean Herbicides. Milos Zaric*[1], Bruno Canella Vieira[1], Barbara Vukoja[1], Greg Kruger[1], Kelly W. Bruns[1], Sam E. Wortman[2]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]University of Nebraska-Lincoln, Lincoln, NE (012)

The establishment of industrial hemp fields in areas adjacent to herbicide-tolerant crops has raised questions regarding crop vulnerability to herbicide drift. The objective of this study was to examine industrial hemp sensitivity to the drift of herbicides registered for use in corn and soybean. Herbicide solutions (2,4-D, dicamba, glufosinate, glyphosate, imazethapyr, lactofen, mesotrione) were mixed at 140 L ha^{-1} carrier volume and sprayed in the low-speed wind tunnel (3.6 m s^{-1}) with conventional and air inclusion flat fan nozzles (TP95015EVS and AI95015EVS, respectively) at 207 kPa. At application time plants (20-25cm) were positioned inside the wind tunnel at different downwind distances up to 12 m from the nozzle. Herbicide solutions contained fluorescent tracer at 3 g L^{-1} for spray deposition evaluation using mylar cards. Plant above ground biomass was harvested 21 days after treatment. The study was conducted twice in a randomized complete design with four replications per treatment. Results indicated herbicide drift was influenced by nozzle design, where applications with conventional and air inclusion nozzles had 5% of the spray deposits reaching 5.9 and 2.0 m downwind, respectively. Industrial hemp had greater sensitivity to glyphosate, glufosinate, and mesotrione spray drift, with plants having 50% biomass reduction for TP95015EVS at 19.3, 8.7, 9.3 m while for AI95015EVS at 4.1, 4.0, and 2.9 m downwind, respectively. Herbicide drift from adjacent corn and soybean fields needs to be considered a high-risk situation for industrial hemp production. If additional drift mitigation techniques are not employed industrial hemp biomass can be drastically reduced.

Rescue Herbicide Treatments for Palmer Amaranth Control in Grain Sorghum. Rui Liu*[1], Vipan Kumar[1], Sachin Dhanda[1], Monica R. Marrs[2], Taylor Lambert[1]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Manhattan, KS (013)

The widespread evolution of glyphosate-resistant (GR) Palmer amaranth is a serious management challenge for growers in the Central Great Plains, including Kansas. Limited POST herbicide options further complicate the management of GR Palmer amaranth in grain sorghum. The objective of this study was to determine the effectiveness of off-labelled POST herbicides (as rescue treatments) on crop injury and Palmer amaranth control in grain sorghum. Field study was established at Kansas State University Agricultural Research Center near Hays, KS in 2021. The experimental site had a natural infestation of GR Palmer amaranth. A total of nine herbicide programs (at field used rates), including dicamba alone or in combination with atrazine, pyridate, or halosulfuron-methyl, respectively; 2, 4-D alone or with prosulfuron or dicamba + dichlorprop-p; pyrasulfotole + bromoxynil alone or with atrazine were tested. All treatments were applied at sorghum boot stage (off-label timing) and Palmer amaranth was at inflorescence initiation stage. Treatments were arranged in randomized complete block design with 4 replications. Data on percent visual control of Palmer amaranth and sorghum injury were assessed at 2, 4, and 8 weeks after treatment (WAT) using a scale of 0 to 100%, where 0 represents no control/injury and 100%

represents complete control/ plant death. The aboveground biomass of Palmer amaranth was collected using a 1-m^2 quadrat placed at the center of the plot at 8 WAT. Among all of the tested herbicide programs, dicamba alone provided the highest control (48 to 68%) of Palmer amaranth, followed by 2, 4-D + prosulfuron (37 to 68%), and dicamba + pyridate (43 to 66%). Similarly, the Palmer amaranth biomass reduction (66, 69, and 88%, respectively) was consistent with % visual control for those three treatments. In conclusion, these results suggest that late-season applications of tested POST herbicides (rescue treatments) would not provide effective control of tall GR Palmer amaranth in grain sorghum.

Multiple Herbicide-Resistant Kochia in the Southcentral Great Plains: Field Survey and Management. Sachin Dhanda*[1], Vipan Kumar[1], Rui Liu[1], Misha R. Manuchehri[2], Muthukumar V. Bagavathiannan[3], Phillip Stahlman[1]; [1]Kansas State University, Hays, KS, [2]Oklahoma State University, Stillwater, OK, [3]Texas A&M University, College Station, TX (014)

Kochia (*Bassia scoparia* L.) is one of the most troublesome summer annual broadleaf weed species in the southcentral Great Plains (SGP). Main objectives of this research were (1) to determine the frequency and distribution of herbicide-resistant (HR) kochia in the SGP region and (2) investigate the effectiveness of auxinic herbicides for controlling glyphosate-resistant (GR) kochia. For objective 1, about 86 kochia populations collected from Kansas, Oklahoma, and Texas were separately tested in a greenhouse at Kansas State University Agricultural Research Center (KSU-ARC) near Hays, KS using 50-cell plastic trays containing commercial potting mixture with glyphosate (1260 g ha^{-1}), atrazine (1120 g ha^{-1}), dicamba (560 g ha^{-1}), fluroxypyr (235 g ha^{-1}), chlorsulfuron (26 g ha^{-1}), and a premixture of dichlorprop/dicamba/2,4-D (374/186/186 g ha^{-1}). Percent survival frequency based on dead and live counts was calculated at 21 days after treatment (DAT). For objective 2, separate dose-response experiments of 2,4-D, dichlorprop, dicamba, and premixture of 2,4-D/dichlorprop/dicamba were conducted at KSU-ARC in a fallow field infested with GR kochia. Results indicated that all surveyed populations were potentially resistant to glyphosate and chlorsulfuron with > 20% survival frequency. Several populations exhibited putative multiple resistance to glyphosate, chlorsulfuron, atrazine, and dicamba. About 7-, 59-, and 6-times lower dose of 2,4-D/dichlorprop/dicamba premix was needed to achieve an excellent control (90%) of GR kochia as compared to standalone treatments of dichlorprop, 2,4-D, and dicamba, respectively. These results indicate the existence of multiple HR kochia in SGP region and highlights 2,4-D/dichlorprop/dicamba as viable option for GR kochia control.

Tracking Herbicide-Resistant Weeds in California Rice Through a Community-Driven Approach. Aaron Becerra-Alvarez*, Kassim Al-Khatib; University of California, Davis, CA (015)

The continued use of herbicides along with no crop rotations, has led to a large incidence of herbicide-resistant weeds in California rice. In support of managing herbicide-resistant weeds, the University of California (UC) Rice Weed Group and the California Rice Research Board adopted a community-driven approach to confirm or disprove suspected herbicide resistance in growers' fields. The Herbicide Resistance Weed Screening Survey invites rice growers to collect and submit weed seed samples with suspected resistance to test against registered herbicide modes of action by means of a whole-plant assay method. Survey data from 2015 to 2020 demonstrate watergrass species (*Echinochloa* spp.), smallflower umbrella sedge (*Cyperus difformis* L.) and bearded sprangletop [*Leptochloa fusca* (L.) Kunth] have been the most prominent species submitted. The group 2 (ALS-inhibitors) and group 5 (PSII-inhibitor) herbicides have the highest frequency of resistance with greater than 83% of samples demonstrating resistance to the five available herbicides. The group 1 (ACCase-inhibitor) and group 15 (VLCFAs-inhibitor) demonstrated 58% and 44% of resistance, respectively. Groups 4 (auxin mimics), 13 (DOXP-synthase inhibitor), and 14 (PPO-inhibitor) demonstrated less than 7% resistance. Multiple resistance with up to five modes of action was observed with higher frequency for two watergrass species, barnyardgrass [*E. crus-galli* (L.) Beuv] and late watergrass [*E. phyllopogon* (Stapff). Koss.]. The Herbicide Resistance Weed Screening Survey allow UC researchers to better track herbicide-resistant weeds and discover emerging biotypes. The community-driven approach of this survey reveals an allied collaborative effort by the UC and the California rice industry in addressing herbicide resistance.

Performance of a New Broad-Spectrum Herbicide in California Rice: Weed Control and Rice Response to Pyraclonil. Sarah L. Marsh*, Aaron Becerra-Alvarez, Alex R. Ceseski, Saul Estrada, Kassim Al-Khatib; University of California, Davis, CA (016)

California rice (*Oryza sativa*) production faces more herbicide-resistant weeds than any other crop or region in the United States, and new weed management tools are needed. Pyraclonil is a novel PPO-inhibiting active ingredient being evaluated in California water-seeded rice. This new chemistry has activity on a broad spectrum of rice weeds including early and late watergrass (*Echinochloa spp.*), smallflower umbrellasedge (*Cyperus difformis*), ricefield bulrush (*Scirpus mucronatus*), and ducksalad (*Heteranthera spp.*) which are present in many California rice fields. Over the course of three years, NAI-1883 (a granular formulation of 1.8% pyraclonil) was evaluated in combination with other herbicides to access the efficacy and rice response of a season-long herbicide program. The programs included NAI-1883 at 300 g ai/ha applied the day of seeding in combination with propanil, clomazone, benzobicyclon+halosulfuron, thiobencarb, bispyribac-sodium, penoxsulam, florpyrauxifen-benzyl, and cyhalofop at their respective timings later in the season. Rice injury from NAI-1883 was minimal. The herbicide program of NAI-1883 followed by benzobicyclon+halosulfuron and propanil showed exceptional control of all weeds by 45 days after seeding (100% control). All other treatments showed effective weed control. The program consisting of NAI-1883 followed by propanil was effective in controlling most weeds but recorded reduced control of early and late watergrass (<89% control) and ricefield bulrush (87% control). Harvest evaluations recorded acceptable yields for all pyraclonil treatments, ranging from 10913.73 kg/ha to 12179.17 kg/ha. As an additional tool for California weed control, pyraclonil shows effective weed control and minimal injury on rice.

California Weedy Rice Populations Response to Clethodim. Rasim Unan*, Liberty B. Galvin, Kassim Al-Khatib; University of California, Davis, CA (017)

Weedy rice (*Oryza sativa* f. *spontanea* Roshev.) is one of the important weeds in California and it is difficult to control. The aim of this study was to determine the response of California weedy rice populations to clethodim herbicide applications. Clethodim is an ACCase-inhibiting cyclohexanedione herbicide. Clethodim was applied at 8 rates (0.0, 9.4, 18.8, 37.5, 75, 150, 300 and 600 g ai ha^{-1}) on 5 weedy rice accessions commonly referred to accession (1, 2, 3, 4, 5) and

M206 rice variety. The experiment was conducted on complete randomized block design with 8 replications in the greenhouse. The herbicide was applied with 0.25% nonionic surfactant (v/v). Dose–response curves based on the log-logistic model were used to determine the effective dose that provides 90% (GR90 values) weedy rice control. All weedy rice accessions and a rice cultivar had different response to herbicide treatment. Clethodim GR90 doses ranged from 19-107 g ai ha^{-1} for weedy rice and cultivated rice variety as well. While accession 4 was determined as the most sensitive, M206 was determined as the most resistant in tested plants. In addition, accession 5 was 3.6-fold resistant compared to accession 4 and M206 was 5.7-fold resistant compared to accession 4. GR90 values are 30.4, 38.2, 43.4, 18.7, 66.5, and 106.9 g ai ha^{-1} for accessions 1, 2, 3, 4, 5, and M206, respectively. Dose response order was determined as M206>5>3>1>2>4. This finding indicated that clethodim has a great potential as a spot treatment for the management of weedy rice.

A Cost Benefit Analysis of Crop Rotations in California Rice Systems. Sara E. Rosenberg*[1], Whitney Brim-DeForest[2], Bruce Linquist[1], Luis Espino[3], Kassim Al-Khatib[1], Michelle M. Leinfelder-Miles[4], Cameron M. Pittelkow[1]; [1]University of California, Davis, CA, [2]University of California Cooperative Extension, Yuba City, CA, [3]University of California Cooperative Extension, Oroville, CA, [4]University of California Cooperative Extension, Stockton, CA (018)

Paper withdrawn

Field Disturbance and Greenhouse Irrigation Timing Effects on Italian Ryegrass Control with Pyroxasulfone. Traci A. Rauch*, Joan M. Campbell; University of Idaho, Moscow, ID (019)

Italian ryegrass is an annual grass weed that causes significant yield loss in the wheat growing region of the PNW. Pyroxasulfone is a group 15, preemergent herbicide used to control Italian ryegrass in wheat and legumes. Soil surface disturbance and rainfall timing after herbicide application may affect the efficacy of pyroxasulfone. Studies were initiated in the field fall 2015, 2017, 2018 and 2019 to evaluate the effect of disturbance on Italian ryegrass control in winter wheat with pyroxasulfone and pyroxasulfone/carfentrazone applied at four application timings. The herbicides were applied at the highest labeled rate for 2015 at pre fertilization, post fertilization, post plant no germination and post plant with wheat seed germination. The experimental design was a randomized complete block with four replications. Italian ryegrass control was evaluated visually where 0% represented no control and 100% represented complete weed control. In 2015, Italian ryegrass control was best with pyroxasulfone alone (90%) or with carfentrazone (89%) applied post plant with germination but did not differ from pyroxasulfone/carfentrazone post plant no germination. At a low Italian ryegrass population site in 2017, application timing did not affect Italian ryegrass control and ranged from 80 to 94%. Italian ryegrass control in 2018 was best with pyroxasulfone/carfentrazone applied at the post plant with germination (89%) but did not differ from pyroxasulfone alone or with carfentrazone post plant no germination and pyroxasulfone post plant with germination (72 to 83%). In 2019, Italian ryegrass control was similar for all timings (93 to 83%), except pre fertilization which had reduced grass control. In the greenhouse, studies were established to evaluate irrigation timing effect on Italian ryegrass control. Italian ryegrass was planted into dry potting soil and sprayed with pyroxasulfone. Pots were irrigated to soil saturation at 0, 8,15, 22, 36, 50, and 64 DAT. Pots with untreated plants were included. The study is arranged as a randomized complete block with 4 replications. In 2019 at all irrigation timings, no Italian ryegrass plants emerged. In 2022, Italian ryegrass plants emerged at 0 and 36 DAT but were very small compared to the untreated check and most eventually died. These greenhouse studies indicate that pyroxasulfone can be applied to dry soil, activated up to 64 days after application by irrigation or rainfall and still effectively control Italian ryegrass.

Acifluorfen Provides Selective Weed Control in Sugarbeet. Nevin Lawrence*[1], Andrew R. Kniss[2]; [1]University of Nebraska-Lincoln, Scottsbluff, NE, [2]University of Wyoming, Laramie, WY (020)

In 2021 an emergency-use herbicide label was granted for the use of acifluorfen in sugarbeet in several counties of Colorado and Nebraska for control of glyphosate-resistant Palmer amaranth. However, acifluorfen had not been previously tested for Palmer amaranth control in sugarbeet within the High Plains sugarbeet production region. Therefore, in 2021 two studies, one to investigate crop safety and another to investigate weed control efficacy, were conducted in Scottsbluff, NE. Both studies were designed as dose-response studies with acifluorfen rates of 0, 70, 140, 210, 280, and 350 g ai ha^{-1}, and were planted on April 30. The crop safety study was kept weed-free for the entirety of the experiment and acifluorfen was applied at 6 true-leaf (TL) sugarbeet growth stage, the earliest labeled application timing. The weed control efficacy study was kept weed-free until Palmer amaranth emergence was observed, and then acifluorfen was applied when average Palmer amaranth height was 15 cm, corresponding to the 12 TL growth stage of sugarbeet. No sugarbeet stand loss was observed in the crop safety study, and while visual injury was as high as 30% 3 d after treatment, by 28 d after treatment injury was less than 5%. Sugarbeet biomass in the crop response study was not reduced significantly by any acifluorfen rate 28 d after treatment (P = 0.14). Acifluorfen provided =95% Palmer amaranth control at rates >100 g ha^{-1}. Acifluorfen provided effective weed control with acceptable crop response in these studies in 2021.

Acifluorfen Does Not Provide Selective Weed Control in Sugarbeet. Andrew R. Kniss*[1], Nevin Lawrence[2]; [1]University of Wyoming, Laramie, WY, [2]University of Nebraska-Lincoln, Scottsbluff, NE (021)

In 2021 an emergency-use herbicide label was granted for the use of acifluorfen in sugarbeet in several counties of Colorado and Nebraska for control of glyphosate-resistant Palmer amaranth. However, acifluorfen had not been previously tested for Palmer amaranth control in sugarbeet within the High Plains sugarbeet production region. Therefore, in 2021 two studies, one to investigate crop safety and another to investigate weed control efficacy, were conducted in Sheridan and Lingle, WY, respectifvely. Both studies were designed as dose-response studies with acifluorfen rates of 0, 70, 140, 210, 280, and 350 g ai ha^{-1}. An additional rate of 420 g ai ha^{-1} was included for the crop safety trial. The crop safety study was kept weed free for the entirety of the experiment. In both trials acifluorfen was applied at 6 true-leaf (TL) sugarbeet growth stage, the earliest labeled application timing. Common lambsquarters and redroot pigweed were present in the weed control efficacy trial with weeds between 10 to 15 cm in height at the time of application. Acifluorfen rates =70 g ha^{-1} resulted in >20% reduction in sugarbeet biomass 28 d after treatment.

Weed control never exceeded 60% for either common lambsquarters or redroot pigweed at any of the rates used in the experiment. Acifluorfen did not provide effective weed control and caused unacceptable crop response in these studies in 2021.

Herbicide Programs for Pre-plant Weed Control in Wheat and Barley. Chandra L. Montgomery[1], Albert T. Adjesiwor*[2], Jared A. Spackman[3]; [1]University of Idaho, Moscow, ID, [2]University of Idaho, Kimberly, ID, [3]University of Idaho, Aberdeen, ID (022)

Field studies were established in 2021 at two locations (the University of Idaho Kimberly Research and Extension Center, Aberdeen Research and Extension Center) to assess the efficacy and crop safety of different herbicides and mixtures compared to glyphosate. There were 18 treatments arranged in a randomized complete block with four replications. Treatments comprised of a weedy check, glyphosate (870 and 1260 g ae ha^{-1}) and various mixtures of bromoxynil (420 g ai ha^{-1}), carfentrazone (35 g ai ha^{-1}), glufosinate (594 g ai ha^{-1}), paraquat (560 g ai ha^{-1}), pyraflufen (3.64 g ai ha^{-1}), tiafenacil (49.6 g ai ha^{-1}), and topramezone (24.5 g ai ha^{-1}). Winter wheat (*Triticum aestivum*) and winter barley (*Hordeum vulgare*) were planted within 4 weeks after herbicide applications to assess any potential phytotoxicity from these herbicides. Control of broadleaf weeds (common lambsquarters [*Chenopodium album*], kochia [*Bassia scoparia*], and redroot pigweed [*Amaranthus retroflexus*]), was 80% or better in all herbicide treatments except topramezone applied alone (61 to 77%). Similarly, grassy weed (barnyardgrass [*Echinochloa crus-galli*], green foxtail [*Setaria viridis*]) control exceeded 80% in all herbicide treatments except topramezone (68 to 76%) and tiafenacil (77 to 80%). No crop injury has been observed yet from any of the herbicide treatments. Tiafenacil and topramezone herbicides may need to be tankmixed with other herbicides to provide good grassy and broadleaf weed control.

Postemergence Herbicide Combinations for Weed Control in Spring Wheat in Nd. Daniel Guimaraes Abe*, Caleb D. Dalley; North Dakota State University, Hettinger, ND (023)

North Dakota has traditionally been ranked first in spring wheat production in the US; responsible for 47% of US production in 2020. However, competition with weeds can diminish wheat crops yields. Kochia is a particularly troublesome weed with multiple herbicide resistant biotypes found across the northern plains. Controlling kochia is crucial to wheat production as this weed not only reduces wheat yields but can also interfere with harvesting and reduce grain quality. In 2021, an experiment was conducted in Adams County, in southwest North Dakota, to evaluate weed control resulting from postemergence application of various herbicides combinations labelled for weed control in hard red spring wheat. At 23 days after treatment (DAT), kochia control ranged from 62 to 97%. Treatment combinations containing bromoxynil generally provided the best control of kochia, whereas treatments relying on systemic growth regulators, such as fluroxypyr or MCPA, provided only fair or poor control of kochia. At this same evaluation timing, all treatments provided good control (> 80%) of common mallow, and most treatments provided good control (> 78%) of field bindweed, with the exception of halauxifen + florasulam + pyroxsulam + fluroxypyr (0.7 + 0.7 + 15 + 133 g ha^{-1}) and fluroxypyr + tribenuron + thifensulfuron (8.8 + 0.5 + 1.6 g ha^{-1}). At 49 DAT, kochia control was similar to previous evaluations in that combinations that included bromoxynil controlled kochia better than treatments that did not. The summer of 2021 was hot and dry following herbicide application. This resulted in weeds becoming stressed due to lack of soil moisture. Under these conditions, herbicide combination containing bromoxynil, which is primarily a contact herbicide, performed better compared to systemic herbicides applied alone. Spring wheat was not visually injured from any of the applied treatments. While herbicide treatments resulted in differences in weed control, these differences did not result in differences in wheat height or yield due to herbicide treatments. Lack of yield differences may be due to the high variability of yields resulting from the drought conditions this year which severely limited crop production. Further research is necessary to evaluate the effect of these treatments on kochia control under more favorable environmental conditions.

Herbicide Resistance in Downy Brome from Fescue Fields in Oregon. Victor H. Ribeiro*[1], Caio A. Brunharo[1], Carol Mallory-Smith[1], Darrin Walenta[2]; [1]Oregon State University, Corvallis, OR, [2]Oregon State University, La Grande, OR (024)

Downy brome (*Bromus tectorum* L.) is a difficult weed to control in fine fescue (*Festuca* L. spp.) seed-production fields in Northeastern Oregon. In fine fescue, acetyl-coenzyme A carboxylase (ACCase) inhibitors are the most often used herbicides to control downy brome. The objective of this study was to determine if 10 downy brome populations collected from fine fescue fields in Union County, OR, were resistant to the ACCase inhibitors clethodim, fluazifop, quizalofop or the ALS inhibitor sulfosulfuron. Dose-response studies were conducted in the greenhouse at Oregon State University, Corvallis, OR, using a completely randomized design with four replications. Herbicide rates ranging from 0 to 8X were tested for clethodim (X = 136 g a.i ha^{-1}); fluazifop (X = 140 g a.i ha^{-1}); quizalofop (X = 92 g a.i ha^{-1}); and sulfosulfuron (X = 35 g a.i ha^{-1}). Downy brome biomass was collected 21 days after herbicide application, dried, and weighed. Three and four-parameter log-logistic models were fitted to the relative biomass (% of untreated control) data to estimate the dose to achieve 50% growth reduction and resistance ratios. All populations were =7.2- and =13.7-fold resistant to clethodim and fluazifop, respectively, when compared to the susceptible population. All but one population were resistant to quizalofop. All populations were susceptible to sulfosulfuron. Widespread ACCase-resistant downy brome populations are a challenge because there are a limited number of herbicides registered for grass control in fine fescue. Alternative herbicides, including ALS inhibitors, may offer options to control these populations.

Survey of ALS Resistance in Winter Wheat Identifies Target-site Imazamox Resistance in *Secale cereale*. André Lucas Simões Araujo*[1], Neeta Soni[2], Eric P. Westra[1], Camila Ferreira de Pinho[3], Sarah Morran[1], Giuseppe Allegretta[4], Jens Lerchl[4], Philip Westra[1], Franck E. Dayan[1], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Corteva Agriscience, Indianapolis, IN, [3]Universidade Federal Rural do Rio de Janeiro, Seropédica, Brazil, [4]BASF, Limburgerhof, Germany (025)

Feral rye (*Secale cereale*) is a troublesome winter annual grass weed in wheat production in Colorado. Selective in-crop chemical control with post-emergent herbicides is limited to imazamox (Clearfield®) and quizalofop (CoAXium®), due to the plant physiological similarity between wheat and feral rye. Information regarding the current scenario of feral rye resistance to these herbicides is absent. The objective of our research was to perform an imazamox and quizalofop resistance survey to identify resistant populations and subsequently to elucidate the molecular mechanism involved in the identified resistance. Greenhouse herbicide screening was conducted utilizing labelled rates of imazamox and quizalofop to evaluate samples from 50 collection sites. One population of feral rye survived when treated with imazamox, however, quizalofop resistance was not identified. Dose-response results demonstrated that the ED_{50} for the surviving plants was 100-fold more than in the susceptible control. Acetolactate synthase (ALS) gene sequencing revealed a substitution Ser653Thr conferring target-site resistance to imazamox. Identification of the target-site mutation was supported by an *in-vitro* enzyme assay that indicated the resistant biotype required 948µM more imazamox to reach 50% of enzyme inhibition compared to the susceptible control. A model describing the ALS enzyme domain of the resistant plants demonstrated a change in the architecture of the channel generated by the threonine substitution when compared to the susceptible plants that possess serine in position 653. Van der Waals forces were 17.6 and 72.2 kJ mol^{-1} for serine and threonine, respectively. Therefore, imazamox could not interact with the channel resulting in feral rye resistance.

Feral Rye (*Secale cereale*) Control with ACCase Tolerant Wheat in Colorado. Eric P. Westra*[1], Todd A. Gaines[1], Chad Shelton[2]; [1]Colorado State University, Fort Collins, CO, [2]Albaugh, Rosalia, WA (026)

Field trials were conducted from 2018-2020 to evaluate feral rye (*secale cereale*) control and economic returns using the ACCase tolerant wheat production system in Colorado. Field studies were setup using a split-plot design with rye density as whole-plot factor and herbicide treatment as the sub-plot factor. Feral rye was established at five different densities (0,5,15,25 and 50%) based on standardize wheat planting density of 60 lbs $acre^{-1}$. Quizalofop p-ethyl (QPE) was applied in the fall, early spring, and late spring at both 10 and 12 fl oz $acre^{-1}$, as well as a fall and spring split application of 8 and 8 fl oz $acre^{-1}$. All plots were harvested for determining yield, and subsamples were used to calculate the percentage of rye dockage. Net economic returns were calculated using seed and herbicide costs, wheat yields, and average Colorado dockage payment penalties from local grain elevators. There was a significant year effect influenced by different environmental conditions during spring applications of QPE between years and a significant hail event just prior to harvest in 2019. For economic returns in 2020 and 2021, all QPE treatments were significantly different compared to untreated check, but statistically similar among QPE treatments regardless of rate and timing. In 2019 yield, dockage, and net return differences among treatments were less than 2020 and 2021 due to hail event, but four of the seven treatments had significantly higher net returns compared to untreated check treatments averaged across rye densities. Relative to the treatment with maximum economic return, untreated check treatments reduced economic returns by 22.3, 26.3, and 39.7 percent in 2019,2020, and 2021 respectively when averaged across rye densities showing feral rye's potential to negatively impact wheat yields and economic returns. Results from these trials will be used to help provide growers best management recommendations to maximize weed control efficacy and economic returns from the ACCase tolerant wheat production system in Colorado.

Efficacy of Delayed Preemergence Herbicides in Various Winter Wheat Tillage Systems. Caitlyn Carnahan[1], Grace F. Flusche Ogden[1], Misha R. Manuchehri[1], Jason G. Warren[1], Hannah C. Lindell*[1], Lane S. Newlin[1], Justin T. Childers[2]; [1]Oklahoma State University, Stillwater, OK, [2]Oklahoma State University, Marlow, OK (027)

Delayed PRE herbicides can provide season-long Italian ryegrass (*Lolium perenne* L. *ssp. multiflorum* (Lam.) Husnot) control in Oklahoma winter wheat when applied at proper rates and incorporated successfully. Many producers use conventional tillage to prepare fields prior to planting but adoption of conservation and no-till acres is evident. However, crop residue in reduced tillage systems may reduce efficacy of delayed PRE herbicides. To evaluate how previous crop residue might impact DPRE herbicides in Oklahoma winter wheat, a trial was conducted at Perkins, OK during the 2019-20, 2020-21, and 2021-22 growing seasons. Herbicide treatments included metribuzin, pinoxaden, pyroxasulfone, and/or pyroxasulfone + carfentrazone-ethyl applied alone or in tank-mixture in no-till, conservation, and conventional tillage systems. Conservation tillage included a pass of a sweep plow set approximately 10 cm below the soil surface with subsequent rotary hoe action. Conventional tillage systems were disked twice with a tandem disk with a field cultivator following. Crop injury was observed in 2019-20 following pyroxasulfone + metribuzin. In 2019-20, visual ryegrass control prior to harvest was 97 to 99% following pinoxaden POST, pyroxasulfone alone or + carfentrazone-ethyl, pinoxaden, or metribuzin. In 2020-21, pinoxaden applied POST resulted in 100% visual control of ryegrass and 94% less biomass compared to the nontreated. Nontreated and pinoxaden applied DPRE had 98% more ryegrass biomass than any other treatment. In 2019-20, pyroxasulfone + metribuzin resulted in the highest yield, 9% and 22% more compared to pinoxaden DPRE and POST, and the nontreated, respectively. Tillage system affected wheat yield in 2019-20 and 2020-21. Yield decreased ~18% following conventional tillage in 2019 and decreased by ~29% following no-till in 2020 compared to other systems. Soil surface residue influenced by tillage did not affect the efficacy of DPRE herbicides in winter wheat but did affect overall grain yield.

Feral Rye Control with Imazamox and Quizalofop-p-ethyl. Rui Liu*[1], Vipan Kumar[1], Sachin Dhanda[1], Monica R. Marrs[2], Taylor Lambert[1]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Manhattan, KS (028)

Wheat producers have limited herbicide options for in-season control of feral rye. Herbicide-tolerant (HT) wheat technologies such as Clearfield® and CoAXium® allow wheat producers to use post-emergence (POST) applications of imazamox (for Clearfield®) and quizalofop-p-ethyl (for CoAXium®) for grass weed control, including feral rye. The main objectives of this research were (1) to determine the sensitivity of feral rye populations from Kansas wheat fields to imazamox and quizalofop-p-ethyl, and (2) to investigate the effect of feral rye growth stage on the effectiveness of imazamox and quizalofop. Matured seeds of 16 feral rye populations were collected from winter wheat fields in central Kansas during 2018 and 2020. To meet these objectives, two separate greenhouse experiments were conducted at Kansas State University Agricultural Research near Hays, KS. Experiment 1 included dose-response study for imazamox and quizalofop-p-ethyl: 0, 0.25, 0.5, 1, 2, 4, and 8-times the field use rates (52 g ha^{-1} for imazamox, and 62 g ha^{-1} for quizalofop-p-ethyl). Experiment 2 included feral rye seedlings from 3 populations, separately treated with imazamox and quizalofop at two different growth stages (3- to 4-leaf and 2- to 3-tillers). Both experiments were set up in a randomized complete design with four replications. Methylated seed oil (0.5% v/v) was included with all imazamox doses, while nonionic surfactant at 0.25% v/v was included with quizalofop doses. Data on percent visual control and shoot dry weights were collected at 21 days after treatment (DAT). Data were analyzed using a 4- parameter log-logistic nonlinear regression model in R software and ANOVA using PROC MIXED in SAS 9.4. Results from dose-response study indicated that 4 to 27 g ha^{-1} of imazamox was required to reduce 50% of shoot dry biomass (GR_{50} value) for all 16 populations, indicating an almost 7-fold difference between the least sensitive population and the most sensitive. The GR_{50} value for quizalofop-p-ethyl ranged from 0.02 to 4.5 g ha^{-1} (significantly below the field-use rate of 62 g ha^{-1}) for all 16 populations, indicating those populations were highly sensitive to quizalofop-p-ethyl. Results from experiment 2 showed a drastic decline in the efficacy of imazamox when applied to feral rye at 2- to 3-tiller stage compared to 2- to 3-leaf stage; whereas the growth stage did not affect the efficacy of quizalofop. In conclusion, these results suggest that quizalofop use in CoAXium® wheat can help provide effective control of feral rye.

WSWS Project 4. Teaching and Technology

Macro Photography of Weeds: Update. Robert F. Norris*; University of California, Davis, CA (044)

Focus stacking is a process that results in greater depth of field and increased detail for close-up photography. Initially the technique relied on moving the camera in incremental steps to achieve the small changes in focus point needed to produce the stack. Camera shake occurred as the focus point was changed. Settle times between 10 and 20 seconds were needed between each shot to eliminate camera shake. Shooting a single 50-shot stack thus required about 8 minutes. Manufacturers recently introduced cameras with the ability to incrementally focus the lens using the built-in focusing motor. Shooting a 60-shot stack can now be achieved in about 60 seconds. The use of microscope objectives permits magnification higher than is possible with typical 1:1 macro lenses. The desired microscope objective is attached to the front of a 200 mm lens using adapter rings, and the whole stacking process employs a precision computer controlled focusing rail. Long settle times are required to eliminate camera shake and shooting a stack can take as long a half an hour. Panorama software can be used to make large high-resolution macro-photographs. Two axis camera control is necessary to shoot the multiple stacks needed for panoramic focus-stacked macrophotographs.

There and Back Again: A Look at North Dakota Weed Control Research Over 50 Years. Stephanie DeSimini*, Kirk A. Howatt, Joseph T. Ikley; North Dakota State University, Fargo, ND (045)

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

WSWS Project 5. Basic Biology and Ecology

Exploring Herbicide Resistance Patterns to Synthetic Auxin Herbicides with Innovative Molecular Tools. Sofia Marques-Hill*[1], Mahima Krishnan[2], Christopher Preston[3], Chad Sayer[4], Franck E. Dayan[1], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]University of Adelaide, Adelaide, Australia, [3]University of Adelaide, Glen Osmond, Australia, [4]NuFarm Australia, Melbourne, Australia (029)

Synthetic auxin herbicides have 82 reported cases of herbicide resistance, but the complex mechanism of action has limited the understanding of resistance mechanisms in weeds. These herbicides mimic the plant hormone auxin, which interacts in the cell nucleus with the auxin-responsive-genes repressor Aux/IAA and with SCF-TIR1/AFB5 protein complex. Auxin acts as a glue between these proteins, leading to the degradation of Aux/IAAs via ubiquitination, and releasing auxin transcription factors to express auxin responsive genes. Mutations in various Aux/IAA proteins have been reported to confer resistance to some of the auxinic herbicides due to changes in the structure that affect their binding to SCF TIR1/AFB5-auxin complex. These mutations include base substitutions or deletions in or near the degron sequence of Aux/IAA, and were found in *Bassia scoparia*, *Sisymbrium orientale* and *Sonchus oleraceous*. However, resistant plants still are controlled with other auxin herbicides, meaning that cross-resistance patterns are still not fully understood. The objective of this study is to improve understanding of cross-resistance to auxin herbicides by performing an innovative molecular assay based on Wend et al. (2013) methods which allow the detection of auxin binding to Aux/IAA. It involves the transient expression of DNA constructs containing the different Aux/IAA genes flanked by two luciferases and the measurement of their luminescence after treatment with 2,4-D, dicamba, fluroxypyr, MCPA, mecoprop, and dichclorprop. This will allow determining which of these herbicides can still bind to the mutant Aux/IAAs, helping to help to design new effective management strategies for controlling weed herbicide resistant populations.

Seed Shattering Phenology of Problematic Weed Species in Cereal-based Cropping Systems in Northern Great Plains. Het S. Desai*; Montana State University, Bozeman, MT (030)

Harvest weed seed control technology captures and destroys weed seeds during harvest, thus stopping the enrichment of the weed seed bank. Amidst the increasing risk of multiple herbicide-resistant weed biotypes selection, harvest weed seed control can be an additional tool in small grain growers' weed management toolbox. However, limited knowledge about the feasibility of harvest weed seed control in Northern Great Plains is available. Our trials at Southern Agricultural Research Center, Huntley, Montana, USA, in summer 2021 showed that feral rye and downy brome retained >90% seeds at winter wheat physiological maturity. Wild oats also retained >90% seeds at spring wheat physiological maturity. Higher seed retention of all the tested weed species makes them appropriate candidates for the harvest weed seed control. We estimated the per capita daily seed shattering rate and cumulative seed shattering percentage up to 28 days after wheat physiological maturity. These metrics are an indicator of how soon farmers should harvest the wheat after physiological maturity in order to be able to perform harvest weed seed control. Downy brome and wild oats tend to shatter their seeds rapidly in winter and spring wheat, respectively. Therefore, timely harvesting is recommended to capture maximum downy brome and wild oats seeds. Next season, we plan to employ more species to study the seed shattering phenology in spring and winter wheat. Upon satisfactory results of seed shattering phenology trials, we will evaluate the performance of different harvest weed seed control methods, such as chaff lining, impact mill, narrow windrow burning, etc.

Glyphosate Induced Phytohormone Response in Rapid Necrosis Biotype of Giant Ragweed. Crystal D. Sparks*[1], Christopher Van Horn[2], Roland S. Beffa[3], Franck E. Dayan[1], Philip Westra[1], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Bayer CropScience, O'fallon, MO, [3]Senior Scientist Consultant, Frankfurt, Germany (031)

The mechanism of glyphosate resistance in the rapid necrosis biotype of giant ragweed (*Ambrosia trifida)* has yet to be determined. Common target site, and non-target mechanisms have been experimentally excluded. In this study we used RNAseq to investigate response to glyphosate treatment at the transcriptomic level. Changes in expression of phytohormone biosynthesis and response pathways, such as jasmonic acid, were observed. These findings, along with other past experiments, suggest a mechanism that may be related to pathogen response in plants. Upcoming experiments include phytohormone quantification at the metabolomic level, and genome wide mapping of quantitative trait loci.

WSWS PROJECT 1: WEEDS OF RANGE, FORESTRY, AND NATURAL AREAS

A Plant Pathologist Looks at Rangeland Ecology Post Fire, Vol. II. William Cobb*; Cobb Consulting Services, Kennewick, WA (081)

This presentation is the second in a planned series of three presentations. The first presentation was given at the WSWS annual meeting held in Anaheim, CA in March of 2018. The talks have the common subject of a 1,000 plus acre tract of sagebrush steppe which is located in Benton County of Washington, immediately south of the City of Kennewick and immediately east and adjacent to Hwy 395/I-82. This tract appears to have not been farmed or grazed for the last 75 or more years and of this date I have found no evidence to contradict that hypothesis. Historically, this tract of land and much of the area surrounding it was submerged numerous times by the waters of glacial Lake Lewis during the Missoula floods of the last Ice Age. The area is strewn with artifacts of these floods including most notably remnants of Columbia Mammoth skeletons and granite "erratics". The site is bordered on the north and west by actual or planned highway, business and housing development. The tract is bordered on the south by another tract of land which was taken out of dryland wheat production (wheat-fallow-wheat) and diverted into the Conservation Reserve Program (CRP) more than 25 years ago. The diverse grass, forbs and brush species inhabiting this sagebrush steppe site were inventoried in the fall of 2013. In September of 2016, a wildfire burned over 365 acres in the middle of this sagebrush steppe site. Then in August of 2018, a wildfire started in the dry vegetation in the median strip of the highway forming the western border of the site and burned approximately the western third of the CRP field and into the sagebrush steppe site. The second fire left three distinct areas of potential study: a non-burned area in the northwest corner of the site, a very large tract of the site that was burned in the 2018 wildfire and the 365 plus acres burned originally in the 2016 wildfire and burned again in the 2018 wildfire. The area of the site which experienced the two wildfires events (2016 and 2018) has the lowest return rate of the native species inventoried in the fall of 2013. The re-growth from the fire events has also been severely impacted by several years of drought since the last fire in 2018 and further impacted by above normal temperatures during the summer of 2021 with record temperatures in excess of 110^o F observed for extended periods of time in the early summer of 2021.

Management Challenges for Garlic Mustard in Forest Understories. Natalie L. Fronk*, Corey V. Ransom; Utah State University, Logan, UT (082)

Garlic mustard is an invasive biennial mustard found throughout forest understories in the Eastern U.S. and is becoming more common in the West. Management research has focused primarily on mechanical and cultural controls, with chemical control research limited to non-selective herbicides such as glyphosate. The purpose of this study was to determine efficacy of herbicide combinations, rates, and timings in garlic mustard management. From 2018 to 2019, four trials were created in Northern Utah with fall and spring treatments applied in a randomized complete block design. Treatments included applications of 2,4-D, glyphosate, metsulfuron, indaziflam and a premix of penoxsulam and oxyfluorfen. Annual visual ratings indicated that combinations which included metsulfuron, regardless of timing, maintained the highest control with 76.5-100% control the first year following treatment and 48-81.6% control in the second year. In greenhouse studies, dose-response to metsulfuron, glyphosate, triclopyr, and 2,4-D was observed by applying increasing rates to potted garlic mustard plants. When compared to recommended field application rates, LD50 values were lowest for metsulfuron and triclopyr and highest for glyphosate and 2,4-D. Field and greenhouse findings indicate that metsulfuron and triclopyr may be effective in garlic mustard management at relatively low rates, however, impacts on woody plants must be considered when treating populations in forest understory. Though less likely to impact woody plants, 2,4-D and glyphosate are likely to be effective in reducing garlic mustard cover only at high application rates.

Evaluating Control Options for Knapweed in Utah. Cody J. Beckley*, Corey V. Ransom; Utah State University, Logan, UT (083)

Squarrose (*Centaurea virgata*) and Russian Knapweed (*Acroptilon repens*) are invasive noxious weeds which negatively impact native rangeland in central and northern Utah. Current guidelines recommend applying aminopyralid at 4-6 oz/A in the spring or fall to provide effective control. However, necessary re-treatment after 2+ years is commonly reported as necessary by those dealing with knapweed infestation. Research trials established in various parts of Utah may offer further information on how to refine and optimize applications of aminopyralid. In 2013 at Dinosaur National Monument, a trial was conducted to determine whether aminopyralid was effective when applied at half rates to Russian knapweed. During the trial, aminopyralid applied at 3 oz/A provided the same level and duration of control as aminopyralid at 6 oz/A, suggesting that split-applications at lower rates was a possibility for acceptable control. In a separate trial in the same year at Dinosaur National Monument, the effectiveness of broadcast applications to spot spraying was compared. In this trial, no significant difference was observed between broadcast and spot spraying. However, significantly less herbicide was used for the broadcast application, suggesting it may be more critical for aminopyralid uptake to occur through soil and tissue vs tissue only. In 2017, additional trials were established near Randlett and Vernon, Utah to compare aminopyralid rate (3.5 oz/A vs 7 oz/A) and timing (spring vs fall). Data obtained from the Randlett trial have been previously reported by Kitchen and Ransom in 2021. At Vernon, both fall treatments and the spring full rate treatment were more effective at controlling knapweed when compared to the untreated in the 1st and 2nd year after treatment (YAT). In the 3rd YAT only both spring treatments offered significant control compared to untreated. The results of these trials suggest that biennial or triennial re-treatment of knapweed with aminopyralid may be necessary for continual control but can be done with half the commonly recommended rate. Applications should be broadcast applied whenever possible to maximize plant and soil coverage. Environmental conditions such as prolonged drought should also be factored into applications in order to maximize aminopyralid effectiveness.

Using All-in-One Crop Monitor and Weather Stations to Identify Target Windows for Herbicide Applications on Mesquite. Joshua Weinstein*[1], Brian J. Schutte[1], Amy Ganguli[2], Brandi Wheeler[1], David Thompson[1], John Idowu[1]; [1]New Mexico State University, Las Cruces, NM, [2]United States Department of Agriculture: National Institute of Food and Agriculture, Kansas City, MO (084)

Aerial application is an effective method of applying herbicides to control honey mesquite (*Prosopis glandulosa*); however, treatment efficacy is contingent on abiotic and biotic conditions at the time of application. To ensure conditions are suitable, land managers may need to make numerous visits to a treatment site prior to the herbicide application. Alternatively, land managers can deploy environment and crop monitoring devices that provide real-time information on conditions pertinent to herbicide treatment outcomes. In this study, environment and crop monitoring stations (Arable Mark 2) were placed on individual honey mesquite plants in a rangeland in southern New Mexico. The objective was to assess the Arable Mark 2's ability to track mesquite phenology. To address this objective, we associated the Arable Mark 2's vegetation metrics (NDVI, chlorophyll index) with ground observations made according to National Phenological Network standards. Results indicated that changes in NDVI coincided with honey mesquite flowering and leaf development. These results suggest that vegetation metrics on the

Arable Mark 2 can track honey mesquite and indicate phenological windows that are optimal for foliar herbicide applications.

Considerations in the Use of Herbicides for Annual Grass Control in Degraded Arid and Semi-arid Rangeland Restoration. Kevin Gunnell*[1], Melissa L. Landeen[1], Corey V. Ransom[2]; [1]Utah Division of Wildlife Resources, Ephraim, UT, [2]Utah State University, Logan, UT (085)

Chemical control of invasive annual grasses, primarily cheatgrass (*Bromus tectorum*), is one of the primary tools employed to restore degraded rangelands in Western North America. However, herbicides used to control invasive annual grasses also have differential efficacy, different impacts on desirable components of the target community, or inadvertent impacts on the germination of desirable species seeded in conjunction with the chemical treatment. Understanding and leveraging these different attributes of the varied herbicides available is a crucial component in developing successful restoration and integrated pest management (IPM) strategies. We will discuss past, current and ongoing research of some of the most common herbicides used for annual grass control in relation to their use in arid and semi-arid rangeland restoration, particularly their impacts on augmented seeding efforts, in order to outline appropriate areas of use or highlight potential hazards of their use.

Multispectral Satellite Remote Sensing for Leafy Spurge Mapping in Northwestern Colorado. Chloe M. Mattilio*; University of Wyoming, Laramie, WY (086)

After being introduced to the Yampa River in Northwestern Colorado, flooding events have transported leafy spurge (*Euphorbia esula L.*) propagules to river terraces and along irrigation ditches. Leafy spurge spread beyond the river channels has not been assessed. Multispectral satellite imagery was obtained, and bright yellow-green leafy spurge bracts were used to identify and digitize training samples in the summer of 2019. Spectral signatures from training samples for leafy spurge and other landcover were used to train a Random Forest machine learning classification. In the summer of 2021 classification maps were then compared to imagery and ground mapped leafy spurge presence, mismatches were identified, and 271 validation locations were surveyed. At each validation location, leafy spurge cover, other vegetation presence, bare ground, and overstory canopy coverage were recorded. An analysis of variance was used to compare validation location characteristics and classification status (correctly identified leafy spurge, false positive, false negative, and correctly classified other cover). A frequency analysis was conducted for other plant species found at leafy spurge validation locations. Leafy spurge training samples were classified with 96% accuracy, an overall accuracy of 92%, and Kappa of 0.834. Correctly classified leafy spurge locations had higher average leafy spurge coverage and lower average canopy coverage than missed leafy spurge locations. A frequency analysis for other species at validation locations determined that smooth brome, dandelion, and willows were mistaken for leafy spurge. Multispectral remote sensing was successful at identifying leafy spurge, particularly in open areas with dense leafy spurge coverage.

Beyond the Dead Weed - Collaborating to Capture and Share the Benefits of Managing Vegetation to Meet Wildlife, Pollinator and Other Habitat Objectives. Byron B. Sleugh*[1], William L. Hatler[2], Scott Flynn[3], Travis Rogers[4], Charles Hart[5], Sam Ingram[6], Mark J. Renz[7], Brian A. Mealor[8], Timothy S. Prather[9], Jane Mangold[10]; [1]Corteva Agriscience, Carmel, IN,

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Weed scientists often focus mainly on efficacy in vegetation management projects and important questions that may be of concern to a broader cross-section of stakeholders are sometimes not fully addressed. It is important therefore to look beyond the dead weed and focus on collaborating to capture and share the benefits of managing weeds to meet a variety of stakeholder objectives including wildlife, pollinator, or other habitats, or grazing animal production. Collaborative research and/or demonstration projects were initiated with private landowners, university, Local, State, and Federal Agencies, NGOs, and industry partners utilizing various weed management tools in diverse environments across the US. These multi-year, multi-partner collaborations have focused on topics beyond efficacy of herbicides but have focused on topics including but not limited to – response of native forbs, shrubs or trees to herbicide applications, pollinator habitat effects, wildlife response to the control of invasive annual grasses, habitat improvements through weed/brush management, forage response, and long-term ecosystem response to weed or brush control. The study sites include wildlife management areas, utility right of ways, roadsides, conservation or working (grazed) grasslands, National Forests, and others. Outcomes from these projects are currently being communicated or will be communicated to stakeholders through a variety of channels including professional meetings, extension bulletins, informational publications, landowner/land manager meetings, and other venues to help provide site-specific management information to better meet land manager objectives. The summary of these projects shows the importance of multi-year, multi-partner collaborative projects in providing information to land managers and the broader community.

Enterprise Budget Comparisons of Ventenata Control on a Private-Land Ranch of Northeast Wyoming. Marshall Hart*, Brian A. Mealor; University of Wyoming, Sheridan, WY (088)

Invasive species pose a threat to the livelihoods of many people living on rangelands of the western U.S. Economic analyses often find that conservation practices, such as invasive species control, are not economically viable on private ranches, in contrast to what is found at the landscape scale. In northeast Wyoming, *Ventenata dubia* (Leers) Coss is a relatively new invader in the Great Plains ecoregion that threatens forage production on ranches. Our objective was to explore the economic costs of *V. dubia* over a three year period for two options available to a ranch operation: purchasing extra hay to offset losses in forage, and controlling *V. dubia* with herbicide. Using a partial budget analysis, we compare these two options in three invasion impact scenarios using a range of forage utilization rates (affecting rangeland acres) and discount rates. Controlling *V. dubia* with herbicide was a beneficial option over purchasing additional hay in many cases. In fact, in our highest impact scenario or at 50% utilization, it was always cheaper to control *V. dubia*, regardless of the discount rate tested. For lower grazing utilization rates with lower impacts of *V. dubia*, it was cheaper to purchase supplemental hay. There are many ranch-specific differences that may make different options more feasible, and we did not explore options such as reducing herd sizes. Our results indicate that controlling *V. dubia* can be an economically-viable option under certain circumstances.

Enhancing Adaptive Invasive Annual Grass Management Via Landscape-scale Vegetation Monitoring. Brian A. Mealor[1], Andrew C. Cassiday[2], Luke Sander[3], Jaycie N. Arndt*[4], Oakley Ingersoll[2]; [1]University of Wyoming, Sheridan, WY, [2]USDA NRCS, Sheridan, WY, [3]Wyoming Weed and Pest, Sheridan, WY, [4]University of Wyoming, Arvada, WY (089)

Ventenata (*Ventenata dubia* (Leers) Coss.) and medusahead (*Taeniatherum caput-medusae* (L) Nevski.) were identified in Sheridan County, Wyoming in the summer of 2016. Shortly after, the Northeast Wyoming Invasive Grasses Working Group (NEWIGWG) was established as a multi-stakeholder group aimed at containing or eradicating both species. Using vegetation survey and monitoring to inform management is critical for NEWIGWG to answer questions related to species presence, treatment efficacy, and retreatment intervals. From 2017-2021, the group surveyed 42,600 acres prior to treatment, treated 92,209 acres, retreated 7,000 acres, and monitored 4,352 vegetation sampling points throughout Sheridan and Campbell Counties, Wyoming. Additionally, we are evaluating an activated carbon assay protocol to estimate the persistent annual grass seedbank following indaziflam treatments. Vegetation monitoring suggests that single indaziflam applications have not been effective at eradicating ventenata or medusahead 1-3 years after treatment. Indaziflam treatments reduced ventenata and medusahead abundance, but did not have consistent control across the landscape. We also identified two new medusahead populations in 2021. Initial activated carbon assay results suggest that carbon is effective at allowing seedlings to emerge in soils treated with indaziflam to assess seed bank viability. Future work will include a statewide landscape-scale invasive annual grass monitoring network, field assessment of the activated carbon assay protocol, stakeholder driven research, and continued collaborative efforts toward managing invasive annual grasses.

Does Annual Grass Invasion Affect Rangeland Drought Resistance? Marshall Hart*, Brian A. Mealor; University of Wyoming, Sheridan, WY (090)

Ventenata dubia (Leers) Coss has recently invaded Wyoming. Following landscape scale control efforts using 123 g ae ha^{-1} of aminopyralid plus 123 g ai ha^{-1} of imazapic in 2017, and 73 g ai ha^{-1} of indaziflam in 2018, we collected biomass samples in treated and non-treated plots in two wet and two dry years. We answer questions on how annual grass, perennial grasses, and drought interact in this region using a linear mixed-model approach. We used perennial grass, annual grass, relative annual grass, and total plant biomass as dependent variables. We used annual grass biomass, perennial grass biomass, precipitation (high or low), and their interactions as fixed effects, with a random effect of plot nested within site. Annual grasses interacted with precipitation, leading to an inverse relationship between annual grass biomass and perennial grass biomass during drought, and a positive relationship in wet years ($p<0.05$). Perennial grasses did not exert the same influence on annual grasses ($p=0.74$), and there was no interaction between perennial grasses and precipitation affecting annual grasses ($p=0.99$). Annual grasses responded similarly to drought as perennial grasses as evidenced by: the relative proportion of annual grasses remaining constant regardless of precipitation ($p=0.10$), plots having similar total biomass in drought years regardless of functional group dominance ($p=0.20$), and the variation ($p=0.81$) and percent change ($p>0.89$) of total biomass from year to year being similar regardless functional group dominance. These patterns show that *V. dubia* may become a larger issue in this region due to drought.

Pairing Monitoring and Research to Manage Early-stage Downy Brome Invasion at the Landscape Scale. Julie A. Kraft*; Sublette County Weed and Pest, Pinedale, WY (091)

The invasion of *Bromus tectorum,* Downy Brome or cheatgrass threatens the Western sagebrush steppe. The degree of infestation varies across the West. In Sublette County, Wyoming we have been managing the relatively new invasion of cheatgrass for ten years. Our taskforce project implements research and monitoring to keep our management plan dynamic and use the best tools and techniques available. Ten years of monitoring data paired with ongoing research and an active collaborative partnership allows us to fight this important battle and prevent the spread of cheatgrass into resilient sage brush communities that our essential for sage grouse, mule deer, pronghorn antelope and livestock grazing. Sublette County is 3.2 million acres and 80% public land. We have treated 63,090 acres with the "no fences" for prioritizing areas and combination of funding. Our management program has been designed to treat the invasion at the landscape scale. Combining collaborative monitoring and science we have 4 years of indaziflam plots, teaching us how to modify our program based on the approval of this tool. With indaziflam's longer activity we have adjusted our retreatment interval and will be evaluating how and if we retreat based on soil seed bank. Long-term monitoring data will help us evaluate acres with multiple retreatments over time, determine the correct retreat interval and native plant recovery.

Relative Tolerance of Newly-Seeded Grasses, Forbs, and Shrubs to Indaziflam in Northeast Wyoming. Jodie A. Crose*, Brian A. Mealor; University of Wyoming, Sheridan, WY (092)

Indaziflam is a preemergent herbicide recently labeled for use in rangeland systems. It controls annual grasses with an extended soil residual with minimal impacts to established perennial species richness and abundance. Competition from annual grasses can reduce establishment of newly-seeded species. Indaziflam may be a tool to reduce competition for seeded desirable species. We evaluated establishment of 45 native grass, forb, and shrub species with and without indaziflam one and two years after treatment (June 2020 and 2021). We established the study as a split plot design (+/- indaziflam) with four replications of each species. We applied indaziflam in July 2019 at 73 g ai ha^{-1}. We seeded species in either November 2019 or March 2020 based on each species' recommend planting timing. Plots were hand-weeded twice in each growing season. In 2020, indaziflam treated and control densities for each species were similar except sideoats grama, Idaho fescue, crested wheatgrass, bluebunch wheatgrass, and blue grama, which were all reduced by indaziflam. These differences were maintained for cover of crested and bluebunch wheatgrass and blue grama in 2021. Additionally, indaziflam reduced sandberg bluegrass, muttongrass, and indian ricegrass cover. In 2020, desert biscuitroot and dotted gayfeather density was similar whether indaziflam was applied or not and this trend remained in 2021 despite an overall reduction in forbs. Shrub establishment was low. Establishment was too low for some species to confidently assess tolerance to indaziflam, and more research is needed in this area.

Effects of Introduced Annual Graminoids on Native Vegetation of Rangelands Across Northwestern United States. Andrea De Stefano*[1], Brian A. Mealor[1], Lisa J. Rew[2], Jane

Mangold[2], Corey V. Ransom[3], Lisa C. Jones[4], Timothy S. Prather[4]; [1]University of Wyoming, Sheridan, WY, [2]Montana State University, Bozeman, MT, [3]Utah State University, Logan, UT, [4]University of Idaho, Moscow, ID (093)

Introduced annual graminoids (IAG), such as annual bromes (*Bromus tectorum, B. japonicus*), ventenata (*Ventenata dubia*), and medusahead (*Taeniatherum caput-medusae*), threaten the ecological integrity of native rangelands of western North America. Therefore, it is crucial to understand the relationships between IAG, plant species richness and diversity, site ecological characteristics, and other plant functional groups, particularly with native perennial graminoids. We used data from 69 sites, distributed across four level II EPA Ecoregions in the western USA (Oregon, Idaho, Montana, Wyoming, and Washington) to evaluate these relationships using multiple linear regression models. Exploratory scatterplots indicated a negative relationship between IAG cover and Shannon index, total number of species, and native perennial graminoid cover. However, IAG cover alone was not sufficient to explain the variability of the dataset, being the R^2 value less than 10% in most of the cases. Introducing other plant functional groups, climatic, and soil characteristics improved considerably the proportion of variance explained by the models. Overall multiple linear regression models revealed a negative relation between Shannon index and introduced annual graminoids, native shrubs, introduced perennial graminoid, elevation, daily maximum temperature, soil water supply (cm of water in the first 150 cm of soil), pH, and bulk density. A positive relation was found between Shannon index and mean annual precipitation, introduced annual and perennial forbs, and soil sand. Total number of species was negatively related to IAG, native shrubs, daily maximum temperature, elevation, soil water supply, and sand. It was positively related to mean annual precipitation, daily minimum temperature, introduced annual forbs, native perennial graminoids, slope, soil bulk density, sand, and pH. Native perennial graminoid cover was found negatively correlated with IAG, native and introduced annual forbs, introduced perennial graminoids, native shrubs, daily minimum temperatures, bare ground and rock cover, litter cover, soil clay, and sand, while positively related to soil bulk density. IAG cover was negatively correlated with native and introduced perennial graminoids, native shrubs, native annual forbs, bare ground and rock, and litter cover, while positively to mean annual temperature. Findings suggest that IAG are prone to invade warmer sites, outcompete native and non-native vegetation, decreasing species richness and diversity, and potentially lead important alterations to native ecosystems. Understanding the relationships between IAG, native plant species diversity, and site ecological characteristics will increase our ability to predict which habitats will be more strongly impacted by IAG.

Sagebrush Steppe Plant Community Response and Annual Grass Control After Aerial Application of Indaziflam. Georgia R. Harrison*[1], Lisa C. Jones[1], Eva Strand[1], Harry Quicke[2], Timothy S. Prather[1]; [1]University of Idaho, Moscow, ID, [2]Bayer CropScience, Windsor, CO (094)

Invasive annual grasses such as cheatgrass (*Bromus tectorum)* negatively impact sagebrush steppe ecosystems by altering fuel structure and composition, creating a shift towards more frequent, high intensity fires. The herbicide indaziflam can provide at least 3 years of annual grass control. A study was established near Hailey, ID in Mountain Big Sagebrush (*Artemisia tridentata subsp. vaseyana*) plant communities to assess herbaceous fuel response to indaziflam treatment. The study area was stratified into plant community types based on remotely sensed estimates of shrub and perennial herbaceous vegetation cover. Herbaceous fuel loading was determined by destructively sampling herbaceous plants and litter within 8, 0.25 m^2 quadrats per 900 m^2 permanent assessment plot. Both litter and annual grass biomass was highest overall within herbicide treated areas of low sagebrush cover (<30%). Fuel continuity was measured along 3, 30-m long transects within each plot. Gaps greater than 20 cm long between alive or standing dead vegetation were measured. As expected, areas with high sagebrush cover had fewer and smaller gaps, and overall higher fuel continuity than areas with low sagebrush cover. There were no differences in gap size or abundance within each plant community type by herbicide treatment. This study suggests that in areas where indaziflam reduces annual grass cover, there is not a corresponding reduction in fine fuel continuity and herbaceous fuel biomass from annual grasses. Future work will include modeling potential fire behavior within plant community and treatment groups to assess fire risk and spread.

Florpyrauxifen-benzyl + Aminopyralid with Flumioxazin + Pyroxasulfone for Non-crop Weed Control in U.S. Land Management. William L. Hatler*[1], Byron B. Sleugh[2], Scott Flynn[3], Sam Ingram[4]; [1]Corteva Agriscience, Meridian, ID, [2]Corteva Agriscience, Carmel, IN, [3]Corteva Agriscience, Lees Summit, MO, [4]Corteva Agriscience, Savannah, GA (140)

TerraVue® (Rinskor™ + aminopyralid) is a new herbicide developed by Corteva Agriscience for control of broadleaf weeds, including invasive and noxious weeds, and certain woody plants in non-crop areas. Piper EZ herbicide (flumioxazin + pyroxasulfone) is a new suspension concentrate formulation with activity on select grass and broadleaf weeds in non-crop and bare ground sites. Extensive research with the combination of TerraVue 129-259 g ai/ha + Piper EZ 532 g ai/ha was conducted on non-crop/bare ground weed control across the U.S. in 2020-2021. Trials were predominantly applied pre-emergent in the fall of 2020 or spring 2021, with some early post-emergent applications in early summer 2021. Results indicate overall excellent in-season control of key annual grasses such as downy brome (*Bromus tectorum L.*), foxtails (*Setaria spp.*), wild oat (*Avena fatua*), and Italian ryegrass (*Lolium multiflorum*). Excellent control was also observed on kochia (*Kochia scoparia*), shortpod mustard (*Hirschfeldia incana*), Russian thistle (*Salsola iberica*), and field bindweed (*Convolvulus arvensis*). Late-season mean control at 15-17 weeks after application (WAA), across all grass and broadleaf weeds tested, was 77% for TerraVue 129 g ai/ha + Piper EZ 532 g ai/ha versus 82% for industry standard Method 140 g ae/ha + Esplanade 73 g ai/ha. Mean bare ground at 15-17 WAA was 77% for TerraVue 129 g ai/ha + Piper EZ 532 g ai/ha versus 71% for Method 140 g ae/ha + Esplanade 73 g ai/ha. Based on these results, TerraVue + Piper EZ will be a very effective combination for broad-spectrum annual grass and broadleaf control in non-crop and bare ground vegetation management.

Native Annual, Biennial, Monocarpic, and Short-lived Perennial Species Response to Long-term Cheatgrass Control with Indaziflam. James Sebastian*; Boulder County Open Space, Longmont, CO (141)

Boulder County Open Space (BCPOS) manages properties in the lowland, foothills and mountains of Colorado that provide critical wildlife and pollinator habitat with highly diverse ecosystems. A major concern of BCPOS ecologists is the loss of critical wildlife habitat, ecosystems, and dynamic diversity of native plant species due to cheatgrass and cheatgrass-fueled wildfires. Invasive winter annual grasses, such as cheatgrass (Bromus tectorum L.) are considered serious threats to regional biodiversity. Cheatgrass is an invasive native annual species that creates a drought-induced environment that is highly competitive with native forbs, shrubs, and grass species for early spring moisture. Cheatgrass competes directly with short-lived native annual, biennial, short-lived perennial species that germinate from seed. Indaziflam (Rejuvra®, Bayer CropScience) has been adopted by many land managers throughout Colorado with an open space, natural areas, and grazing labels. Field studies at Colorado State University demonstrated that indaziflam provides superior long-term BROTE control (3 plus years) with no documented injury to native perennial species. Indaziflam is a root inhibiting herbicide. This allows for increased safety of desirable perennial plants that have roots below the layer where the herbicide is active. The first spring after cheatgrass control there are void spaces and gaps between native plants where originally there were dense cheatgrass monocultures. The remnant native plants that exist in these sites take full advantage of the additional moisture and nutrients suddenly available where cheatgrass is controlled. One concern with Rejuvra is the long-term impacts it may have on short-lived native plants that's life-cycles depend upon successful seed reproduction for regeneration. We monitored species diversity, biomass, and flower resources at 14 large-scale, highly diverse sites 3 to 5 years after treatment that are 5 to 40 acres in size in Boulder County. All 14 sites are classified as B1 Natural Heritage Society global significance, high diversity, and rarity ranking. We evaluated the presence or absence of each native species conducted using walk diversity sampling. This sampling method has allowed us to answer dynamic, native species diversity questions on a landscape scale. where cheatgrass is controlled in large-scale operational Rejuvra treated areas. This has been critical for monitoring species on sites with a broad diversity of soils, aspects, slopes, and ecosystem regimes that would be impossible to determine with small plots and quadrats. This offered accurate and practical monitoring on a large-scale. The species diversity trend is an increase in all native forb, grass, shrub, and sub-shrub species as void spaces where cheatgrass originally existed is gradually occupied by native species. We monitored 33 different short-lived native annuals, monocarpic, biennial, short-lived perennial species at these sites. None of the short-lived species have been eliminated. In all cases, short-lived species significantly increased in response to the removal of cheatgrass competition. We have also been extremely concerned with long-term impacts to rare and special concern species. We gps geo-referenced all rare and special concern species at these same 14 sites (1 to 5 years after treatment). Rare species diversity and density has also significantly increased with long-term cheatgrass control. These same species are almost non-existent or extremely low density in immediately adjacent non-sprayed sites with cheatgrass. The geo-referenced sites suggest that the trend for each of the rare species is increasing in response to cheatgrass control. Many of these rare plants increased via emerging from seed. Our findings reinforce the findings of field managers, that cheatgrass and other invasive annual grasses pose a significant threat to native species diversity. For land managers, this management tool provides a long-term control option to begin the restoration process on the millions of cheatgrass infested acres.

Indaziflam Absorption by Downy Brome and Jointed Goatgrass Seeds Reduces Plant Establishment. Scott J. Nissen*[1], Shannon Clark[2], Rachel H. Seedorf[3]; [1]Colorado State University, Ft Collins, CO, [2]Bayer CropScience, Fort Collins, CO, [3]Colorado State University, Fort Collins, CO (142)

Downy brome (*Bromus tectorum* L.) and jointed goatgrass (*Aegilops cylindrica*) are invasive, winter annual grasses common along Colorado's Front Range. Indaziflam (Rejuvra[â]), a pre-emergence herbicide first registered in vine and tree nut crops, was recently approved for applications to rangeland for control of winter annual grasses. Indaziflam provides at least three years of downy brome control and control can extend into a fourth and fifth year; however, it is very difficult to find indaziflam in the soil two years after application. We asked the question: How does indaziflam provide three to four years of control? We hypothesized that due to indaziflam's lipophilic nature it could be absorbed by seeds still retained on the plant and seeds on the soil surface. The amount of indaziflam absorbed would be sufficient to stop grass establishment. To test this hypothesis, we treated downy brome seeds and jointed goatgrass cylinders with indaziflam and imazapic at rates from 5.4 to 175 g ha^{-1} using in greenhouse track sprayer delivering 187 L ha^{-1}. Treated seeds were than planted into field soil and plants were allowed to grow for three weeks under greenhouse conditions. Growth was compared to non-treated controls. In addition, we evaluated the impact of rainfall 1 HAT and 24 HAT and rainfall amounts ranging from 3 to 24 mm to determine if rainfall impacted herbicide performance. Downy brome was so sensitive to indaziflam that establishment was completely eliminated at all rates. Imazapic also inhibited downy brome establishment with an ED_{90} of 67 g ai ha^{-1}. Indaziflam effectively inhibit jointed goatgrass establishment with an ED_{90} of 7.4 g ai ha^{-1} compared to imazapic with an ED_{50} of 175 g ai ha^{-1}. Indaziflam's impact on jointed goatgrass establishment was not significantly impacted by rainfall, indicating that the herbicide was absorbed to the seed coat. These findings suggest that indaziflam's long-term control could result from the fact that multiple generations of seed (those still attached to the plant and those on the soil surface) are exposed to high indaziflam concentrations at the time of application that negatively impact establishment.

Utilization and Response of Native Browse Species in Critical Mule Deer Winter Range to Long-term Cheatgrass Control with Indaziflam. James Sebastian*; Boulder County Open Space, Longmont, CO (143)

Boulder County Open Space (BCPOS) manages properties in the lowland, foothills and mountains of Colorado that provide critical wildlife and pollinator habitat with highly diverse ecosystems. A major concern of BCPOS ecologists is the loss of critical wildlife habitat, ecosystems, and dynamic diversity of native plant species due to cheatgrass and cheatgrass-fueled wildfires. Invasive winter annual grasses, such as cheatgrass (Bromus tectorum L.) are considered serious threats to regional biodiversity. Cheatgrass competes directly with short-lived native annual, biennial, short-lived perennial species that germinate from seed for early spring moisture. Indaziflam (Rejuvra®, Bayer CropScience) has been adopted by many land managers throughout Colorado with an open space, natural areas, and grazing labels. Field studies at Colorado State University demonstrated that indaziflam provides superior long-term BROTE control (3 plus years) with no documented injury to native perennial species. Indaziflam is a root inhibiting herbicide. This allows for increased safety of desirable perennial plants that have roots below the layer where the herbicide is active. The first spring after cheatgrass control there are void spaces and gaps between native plants where originally there were dense cheatgrass monocultures. The remnant native plants that exist in these sites take full advantage of the additional moisture and nutrients suddenly available where cheatgrass is controlled. One concern with Rejuvra is the long-term impacts it may have on short-lived native plants that's lifecycles depend upon successful seed reproduction for regeneration. We monitored species diversity, biomass, and flower resources at 14 large-scale, highly diverse sites 3 to 5 years after treatment that are 5 to 40 acres in size in Boulder County. All 14 sites are classified as B1 Natural Heritage Society global significance, high diversity, and rarity ranking. We evaluated the presence or absence of each native species conducted using walk diversity sampling. This sampling method has allowed us to answer dynamic, native species diversity questions where cheatgrass is controlled in operational Rejuvra treated areas. This has been critical for monitoring species on sites with a broad diversity of soils, aspects, slopes, and ecosystem regimes that would be impossible to determine with small plots and quadrats. This offered accurate and practical monitoring on a large-scale. The species diversity trend is an increase in all native forb, grass, shrub, and sub-shrub species as void spaces where cheatgrass originally existed is gradually occupied by native species. We monitored 33 different short-lived native annuals, monocarpic, biennial, short-lived perennial species at these sites. None of the short-lived species have been eliminated. In all cases, short-lived species significantly increased in response to the removal of cheatgrass competition. We have also been extremely concerned with long-term impacts to rare and special concern species. We gps geo-referenced all rare and special concern species at these same 14 sites (1 to 5 years after treatment). Rare species diversity and density has also significantly increased with long-term cheatgrass control. Many of these rare plants increased via emerging from seed. These same species are almost non-existent or extremely low density in immediately adjacent non-sprayed sites with cheatgrass. Over the past 5 years we have also gathered native forb, sub-shrub, and perennial grass seed from sprayed sites and have successfully broadcast spread seed to other locations where we've sprayed indaziflam to control cheatgrass. Broadcast spreading desirable native species seed has increased species diversity on many of our properties where cheatgrass has significantly impacted natives. Our findings reinforce the findings of field managers, that cheatgrass and other invasive annual grasses pose a significant threat to native species diversity. For land managers, this management tool provides a long-term control option to begin the restoration process on the millions of cheatgrass infested acres.

Assessing Community Resilience to Annual Grass Control in Sagebrush Steppe. Lisa C. Jones*, Georgia R. Harrison, Timothy S. Prather; University of Idaho, Moscow, ID (144)

Invasive annual grasses negatively impact sagebrush steppe by decreasing native plant diversity and shortening fire return intervals. An herbicide that has a long soil residual, such as indaziflam, can deplete invasive plant seed banks while releasing native plants from competition. But there is concern that such an herbicide can delay native plant recruitment from the seed bank. Indaziflam and indaziflam + imazapic (70 and 84 g/ha, respectively) were aerially applied within a mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*)-dominated pasture near Hailey, ID in fall 2019. We monitored vegetation composition one- and two-years post-treatment. Herbicide applications controlled annual grasses (*Bromus tectorum* and *B. japonicus*) by 47 to 100% the first year, and 79 to 100% the second year, compared to plots without herbicide. Two years post-treatment, native perennial herbaceous diversity and cover were similar in treated and untreated plots, indicating no plant response due to release from competition. However, 2021 was an extremely dry year so plants may have lacked adequate moisture to take advantage of high annual grass control. Native annual forb cover was higher in untreated plots compared to treated plots, though cover was generally low (mean 5% in untreated plots). Within treated plots, although native plant cover was variable, neither slope, aspect, nor plant community type (a proxy for soil type) correlated with native plant cover. These findings provide no evidence that herbicide application has substantially impeded native plant recruitment. We will continue to monitor plots to assess long-term control and plant community response.

Effects of Indaziflam Application Timing on Annual Grass Control at Seven Rangeland Sites. Beth Fowers*[1], Brian A. Mealor[1], Corey V. Ransom[2], Shannon Clark[3], Derek J. Sebastian[4], Scott J. Nissen[5]; [1]University of Wyoming, Sheridan, WY, [2]Utah State University, Logan, UT, [3]Bayer CropScience, Fort Collins, CO, [4]Bayer, Greeley, CO, [5]Colorado State University, Ft Collins, CO (145)

Preemergent herbicides are widely used for annual grass management. Annual grass germination often occurs following sufficient fall precipitation, so pre-emergent herbicides need to be applied with adequate time for precipitation-driven incorporation before germination or emergence. Effective annual grass herbicide treatments must thread the proverbial needle where the herbicide is applied, incorporated, and retains activity throughout the emergence time of the target species. Because of indaziflam's long soil residual, it may be applied for a longer duration prior to fall emergence of annual grasses. Our objectives were to 1) evaluate the effects of different application timings on winter annual grass control with indaziflam alone and mixed with imazapic or rimsulfuron, and 2) evaluate perennial grass tolerance to different application timings of indaziflam alone and mixed with imazapic or rimsulfuron. Different rates and combinations of indaziflam alone and mixed with imazapic and rimsulfuron were applied at three pre-emergent timings at seven sites across Wyoming, Utah and Colorado. We evaluated May, June, July, and August herbicide application timings (application months varied by site). Dominant annual grass species varied among sites: at two sites it was ventenata (*Ventenata dubia*), downy brome (*Bromus tectorum*) at two sites, and Japanese brome (*Bromus japonicas*) at three sites, with one of those three also having a sub-component of downy brome. We recorded canopy cover of target annual grass species and non-target species one and two years after application along with control ratings two years after application. We analyzed data using ANOVA with site, herbicide treatment, and month of application as factors. In general, herbicide treatments reduced target annual grass cover one and two YAT, but magnitude of reduction varied among sites and target species (i.e. ventenata vs. bromes). Indaziflam plus imazapic or rimsulfuron more consistently reduced annual brome cover one YAT than did indaziflam alone. Ventenata cover was greatly reduced by all herbicide treatments one and two YAT. Perennial grass cover increases were less consistent with high variability among sites and treatments. Our results suggest that annual grass control with indaziflam and tank-mix partners is relatively robust across application timings and that susceptibility differs across sites among target species.

WSWS PROJECT 2: WEEDS OF HORTICULTURAL CROPS

IR-4 Weed Science Update - Food Crops. Roger B. Batts*[1], Jerry Baron[2], Venkat Pedibhotla[2]; [1]IR-4 Project HQ, NC State University, Raleigh, NC, [2]IR-4 Project, Raleigh, NC (111)

Residue projects: Data submitted by IR-4 led to just under 650 new uses in 2021. This is above the number of new supported uses in 2020 but less than the five year average. Of these, 75 uses were for herbicides (clopyralid, quizalofop, MCPA) in many different specialty crops, crop groups or subgroups (*Brassica carinata*, bulb onion subgroup, caneberry subgroup, cottonseed subgroup, pennycress, pome fruit, sunflower subgroup, vining small fruit subgroup and wheatgrass). IR-4 submitted six data petitions for herbicides and plant growth regulators to EPA in 2021. Products included tribenuron, fluazifop, rimsulfuron, fomesafen, glufosinate, and trinexapac. These submissions could potentially lead to more than 225 new uses. Thirteen new herbicide magnitude-of-residue studies began in 2021, which could result in more than 45 new uses. Ten new residue studies will begin in 2022. Product Performance projects: Generating Product Performance (efficacy and crop safety) data to support registration of pest management tools in specialty crops continues to be an important and expanding part of the IR-4 annual research plan. This data is often required by registrants and/or states to complete the registration process. The number of on-going herbicide Product Performance studies in 2021 was twenty-five (66 individual trials), with eleven of them beginning in 2021. The 2022 field research plan for herbicides and plant growth regulators includes nineteen (>60 individual trials) continuing or new Product Performance studies. Integrated Solutions projects: IR-4's Integrated Solutions (IS) Program is structured to assist specialty crop growers outside of the traditional single product/single crop residue and product performance research. IS research efforts focus on four areas, 1) pest problems without solutions, 2) resistance management, 3) products for organic production and 4) pesticide residue mitigation. In 2021, there were five active IS projects with herbicides and plant growth regulators (11 individual trials), most of which will continue in 2022. Five new weed control IS studies will begin in 2022 (>20 individual trials), including rice, hemp, hops, stone fruit, pear and date palm.

Weed Control in Specialty Crops Using Bicyclopyrone. Stephen M. Schraer*[1], Pete Eure[2], Cristin Weber[3], Thomas H. Beckett[2]; [1]Syngenta Crop Protection, Meridian, ID, [2]Syngenta Crop Protection, Greensboro, NC, [3]Syngenta Crop Protection, Normal, IL (112)

Bicyclopyrone is an HPPD-inhibitor (Group 27) herbicide and is one of the active ingredients in Acuron® and Acuron GT herbicides. Syngenta is pursuing registrations in sixteen minor use crops: banana, plantain, papaya, pineapple, rosemary, lemongrass, broccoli, garlic, hops, horseradish, sweet potato, bulb onion, green onion, timothy grown for seed, strawberry, and watermelon. Bicyclopyrone offers flexibility in application methods including preplant, preemergence, pre-transplant, row middle, post-directed, and postemergence, depending on crop. Crop tolerance to bicyclopyrone varies by crop, application rate, and application method. Directions for use include not exceeding 50 g ai ha^{-1} bicyclopyrone per acre per crop year, not exceeding one application per year. Soil applications will provide 3-4 weeks of residual control or partial control of annual grass and broadleaf weeds. Bicyclopyrone will provide an additional active ingredient, and in some cases, a new site of action for managing herbicide-resistant weeds in specialty crops with limited weed control options. Important: Always read and follow label instructions. Some products may not be registered for sale or use in all states or counties. Please check with your local extension service to ensure registration status. Acuron and Acuron GT are not registered for sale or use on banana, plantain, papaya, pineapple, rosemary, lemongrass, broccoli, garlic, hops, horseradish, sweet potato, bulb onion, green onion, timothy grown for seed, strawberry, and watermelon and are not being offered for sale. Acuron is a Restricted Use Pesticide. Acuron® and the Syngenta logo are trademarks of a Syngenta Group Company.

Auxinic Herbicides Injury to Grapevines. Natalia Garcia*[1], Franck E. Dayan[2], Luis A. Avila[3]; [1]Federal University of Pelotas, Fort Collins, CO, [2]Colorado State University, Fort Collins, CO, [3]Universidade Federal de Pelotas, Pelotas, Brazil (113)

Paper withdrawn

Residual Weed Management in Western Pecans with Penoxsulam + Oxyfluorfen. Jesse M. Richardson*[1], Spencer Samuelson[2], William B. McCloskey[3], Brian J. Schutte[4], Kelly A. Backscheider[5]; [1]Corteva Agriscience, Mesa, AZ, [2]Corteva Agriscience, Bryan, TX, [3]University of Arizona, Tucson, AZ, [4]New Mexico State University, Las Cruces, NM, [5]Corteva Agriscience, Franklin, IN (114)

Field studies were conducted in Arizona, New Mexico and Texas to investigate residual weed management with penoxsulam + oxyfluorfen on pecan orchard floors. Herbicides were applied with either a tractor-mounted or backpack sprayer. Results demonstrated that when preemergence herbicides were applied at both dormant and early summer timings in Arizona, overall weed control was better than with a single spring timing. In NM, penoxsulam + oxyfluorfen provided more than 90% control of weed species for at least 17 weeks when applications were made in April and June; no injury to the pecan trees was detected.

Simulated Off-Target Drift of Florpyrauxifen-benzyl in Orchards and Vineyards. Deniz Inci*, Brad Hanson, Kassim Al-Khatib; University of California, Davis, CA (115)

California rice growers heavily rely on herbicides between May and mid-July when nearby orchards and vineyards are at growth stages sensitive to herbicide drift. Florpyrauxifen-benzyl is a new synthetic-auxin rice herbicide and is anticipated to be registered in California. This study aims to develop data on relative tree and vine crop sensitivity to simulated drift rates of florpyrauxifen-benzyl prior to its launch in the state. Florpyrauxifen-benzyl was applied at 0.5%, 1%, 3%, and 10% of the use rate in rice, 30 g ai/ha. Trees and vines were subjected to simulated drift treatments in mid-June during both the 2020 and 2021 growing seasons. Visual injury was rated at 24, 48, and 72 hours and 7, 14, 21, 28, 35, 42, and 90 days after treatments using a scale where 0 means no injury and 100 means complete death. Florpyrauxifen-benzyl symptoms were apparent on all crops; however, the severity of symptoms was greatest on pistachio. Shoot curling and stunting for pistachio; necrotic spots and asymmetrical growth for grape vine; leaf curling and necrosis for almond; epinasty and leaf discoloration for walnut; leaf curling and stunting for peach; and necrosis and excessive branching for prune were the most characteristic symptoms at higher rates. Of the crop tested, prune was the least sensitive and pistachio was the most sensitive to florpyrauxifen-benzyl. With exposure at rates below 3% of the rice use rate, tree crop injury from florpyrauxifen-benzyl appeared to be nonsignificant.

Efficacy of Various Preemergence Herbicides for Season-long Control of Puncturevine in Pumpkin. Cody D. Zesiger*[1], Corey V. Ransom[2], Dan Drost[2]; [1]Utah State University, Ogden, UT, [2]Utah State University, Logan, UT (116)

Puncturevine (*Tribulus terrestris* L.) is a bur forming herbaceous annual found in many Utah cucurbit (pumpkins, melons, watermelons, and squashes) fields. Typical weed management in Utah for these crops includes early season cultivation and postemergence herbicide application supplemented by hoeing. Despite these practices, drought tolerance and recurrent germination allow puncturevine to persist in many fields. Two trials were established in 2021 to evaluate four preemergence herbicides in pumpkins grown on plastic mulch using subsurface drip irrigation or grown on bare ground using sprinkler irrigation. The sites were located at the USU research farm in Kaysville, Utah. Treatments included ethalfluralin (0.63 kg a.i./ha), halosulfuron (0.026 kg a.i./ha), s-metolachor (1.4 kg a.i./ha), and trifluralin (0.84 kg a.i./ha) applied at the respective rates for coarse soils. Plots in both trials were 1.8 by 6 m with four replications utilizing randomized, complete block design. All treatments were applied in June using a CO_2-pressurized backpack sprayer calibrated to deliver 168 l/ha at 276 kPa. In the drip trial, treatments were applied preemergence of weed germination between rows then mechanically incorporated with four passes (two in each direction). In the sprinkler trial, treatments were applied post-plant preemergence over row centers then incorporated with irrigation. Control was evaluated in the sprinkler trial at four and eight weeks after treatment by removing puncturevine biomass from each plot using two 0.26 m^2 quadrats and combining the two samples. The drip irrigated plots were not evaluated four weeks after treatment because the biomass was insufficient for obtaining representative samples using 0.26 m^2 quadrats. Therefore, puncturevine biomass was retained for removal from the whole plot at 8 weeks following treatment. On average, all herbicides controlled puncturevine four weeks after treatment in the sprinkler irrigated plots 51 to 79% in comparison with the untreated check. Eight weeks after treatment the control of all herbicides in the sprinkler plots was 17 to 50% in comparison with the untreated check. In the drip trial, all herbicides controlled puncturevine 53 to 82% compared to the untreated check eight weeks after treatment. In conclusion, it appears that in both trials ethalfluralin and halosufuron may outperform the other two herbicides at coarse soil rates. Four weeks of control can be achieved in pumpkin that is sprinkler irrigated and eight weeks of control is possible between rows of drip irrigated pumpkins. It is unknown why all herbicides failed to provide adequate control in sprinkler plots eight weeks following treatment. Similarly, we cannot explain the variation in control between plots for each herbicide. More research is needed to answer these and other questions.

Early Termination of a Mustard Cover Crop Reduces Risks from Beet Leafhoppers and Potentially Suppresses Weeds in Chile Pepper. Akash Bajagain*, Brian J. Schutte, Erik A. Lehnhoff, Rebecca Creamer, Robert L. Steiner; New Mexico State University, Las Cruces, NM (117)

Overwintered Mustard Cover Crops (OMCCs) incorporated into soil may help reduce pressure from early season weeds in chile pepper (*Capsicum annuum*). However, OMCCs potentially harbor beet leafhoppers (*Circulifer tenellus*) that transmit beet curly top virus to chile pepper. The objectives of this study were to (1) determine biomass yield for an OMCC terminated at different times before onsets of beet leafhopper swarms in spring, and (2) determine weed density and hoeing time responses to an OMCC incorporated at different times before chile pepper seeding in April. To address these objectives, mustard was seeded during October 2019 and October 2020. OMCCs were terminated and incorporated into soil at early-March, mid-March, and early-April, which corresponded to 8, 6, and 4 weeks before chile pepper seeding, respectively. At 4 and 8 weeks after chile pepper seeding (WAS), weed densities and hand-hoeing times were determined and compared against non-cover controls. Beet leafhopper monitoring indicated that regional swarms initiated on April 19, 2020 and April 5, 2021. OMCC biomass increased as termination date changed from early March to early April. Maximum OMCC biomass was 820 g m^{-2} in 2020, 591 g m^{-2} in 2021. In 2020, the OMCC terminated in mid-March suppressed weeds at 4 and 8 WAS, and reduced hoeing time at 4 WAS compared to OMCC incorporated early-March. In 2021, the OMCC terminated in mid-March suppressed weeds at 4 WAS. These results suggest that OMCCs terminated in mid-March evade regional swarms of beet leafhoppers and possibly improve weed management in chile pepper.

Flaming and Cultivation Strategies to Control Weeds in Snap Beans. Ed Peachey*, Andrew Nagy; Oregon State University, Corvallis, OR (118)

Nonchemical weed control strategies other than cultivation are in short supply in dicot crops such as snap beans, particularly strategies that target weeds within the seed row. A common practice is the use of flame weeding in stale seedbeds just before snap beans emerge. Delaying the flaming operation as long as possible improves weed control but also may jeopardize yield. Current cultivation strategies do not provide effective in-row weed control. While RTK and other guidance systems allow closer cultivation with lower risk of damage to the crop, weeds still persist in a 10 cm or larger band in the row. An untested option is aggregated in-row seed placement that facilitates cultivation with in-row cultivators such as the Robovator. However, the effect of aggregated planting arrangements on snap bean yield is a primary concern of producers. Experiments were conducted over two years to test the effect of near-emergent propane flaming and aggregated in-row seed placement on yield of the snap bean variety OR-5630, the variety most commonly seeded in Western Oregon. Propane flame was applied at 48 or 96 l propane ha^{-1} to a 25 cm band above the seed row (144 to 288 l ha^{-1} effective area rate) just before and during emergence of snap beans. Flame weeding reduced yield by as much as 9%, even when less than 1% of the crop was visible during the 'cracking' stage. For the planting-arrangement study, snap beans were aggregated in the seed row so that from 58 to 79% of the row was free of bean seedlings. Crop yield averaged over two years of the study did not decline as the non-seeded area in the row increased, indicating that alternative and aggregated seeding patterns have potential to increase in-row access to robotic cultivators and improve mechanical weed control efficiency.

Overview of Current UCD Research on Chemical Control of Branched Broomrape in Processing Tomato, Including Crop Safety and Efficacy of Israeli Developed PICKIT Decision Support System. Matthew J. Fatino*; University of California, Davis, CA (130)

Recent detections of branched broomrape in California tomato fields have led to interest in management strategies for this regulated noxious weed. A decision support system and herbicide program, known as PICKIT, was developed in Israel, and has provided successful management of Egyptian broomrape in tomato. Research began in 2019 to determine if the PICKIT system could be adapted to manage branched broomrape in California processing tomatoes and to provide herbicide registration support data. Treatments based on the PICKIT system were evaluated in 2019, 2020, and 2021 for crop safety on processing tomato. 2019 and 2020 studies evaluated sulfosulfuron paired with imazapic. There were no differences in phytotoxicity or tomato yield among treatments. In 2021, imazamox was evaluated instead of imazapic. Imazamox injury was observed and included stunting and leaf and stem discoloration; however, there were no differences in tomato yield. A rotational crop study was conducted in which a tomato crop received treatments in 2019 and common rotational crops were evaluated in 2020. Corn planted after sulfosulfuron suffered chlorosis and stunting. A study was conducted in 2020 in an infested field to evaluate the efficacy of the sulfosulfuron and imazapic. There was a trend in which the PICKIT treatments had less broomrape emergence than the non-PICKIT treatments, however, there were no differences in broomrape emergence among PICKIT treatments. In 2021, an efficacy study focused on imazamox was conducted but there was no broomrape emergence. Severe injury was observed and the two highest rates of imazamox significantly reduced yield.

Evaluating Flumioxazin Application Timing and Hilling on Efficacy and Crop Safety in Potato. Harlene M. Hatterman-Valenti*, Collin Auwarter; North Dakota State University, Fargo, ND (131)

Most nightshade species are alternate hosts for insects and diseases that attack potatoes such as Colorado potato beetle and late blight. Eastern black nightshade (Solanum ptycanthum Dun.) has been recognized by growers as one of their worst weed problems. This may be due to grower reliance on metribuzin for broadleaf weed management in potato, and the resulting poor nightshade control as well as the reluctance to use herbicides that can control nightshade in a rotational crop because they also have high carryover potential. Flumioxazin provides excellent control of nightshades but has been shown to also cause injury to potato. To alleviate most of the injury to potato, the label restricts use in potato to only 25 states that includes North Dakota. The label further restricts and limits the herbicide application timing and states: "Many weather-related factors, including high wind, splashing or heavy rains or cool conditions at or near potato emergence, may result in potato injury in fields treated with Chateau EZ Herbicide. On occasion this has resulted in a delay in maturity. Understand and accept these risks before using Chateau EZ Herbicide." Furthermore, the label states: "In areas with historically higher amounts of rainfall during the time of preemergence herbicide applications, including the Red River Valley, Minnesota and North Dakota, the requirement for 2 inches of settled soil is critical to avoid crop injury." The objective was to determine the effect of flumioxazin application timing and hilling on efficacy and crop safety for the irrigated processing cultivar 'Russet Burbank'. Treatments included the labeled use rate and half that rate at three application timings: two days after planting (DAP) and no hilling, after regular hilling (9 DAP), hilling 2 DAP and then applying, and then various application timings of flumioxazin and the combination product of metribuzin + metolachlor along with a standard of metribuzin + metolachlor after regular hilling. Results indicated that all treatments provided similar excellent control of broadleaf annual weeds. Plots treated with 0.5X or 1X flumioxazin after an early hilling had the greatest total and marketable yields but this was only greater than one other treatment. Plots treated with 1X flumioxazin after an early hilling or 0.5X flumioxazin after early hilling followed by 0.5X metribuzin + metolachlor after regular hilling had the greatest percentage of marketable yields but this also was only greater than a different single treatment. None of the treatments caused visible potato injury, which was attributed to the lack of rainfall prior to the initiation of irrigation. Future research will include varying irrigation applications following the flumioxazin applications to ensure evaluation of crop safety with the application timings.

WSWS PROJECT 3: WEEDS OF AGRONOMIC CROPS

Metabolic Resistance of *Echinochloa crus-galli* to Florpyrauxifen-benzyl is Affected by Temperature. Luan Cutti*[1], Guilherme M. Turra[2], Carlos A. G. Rigon[3], Crystal D. Sparks[3], Angela Da Cas Bundt[4], Catarine Markus[1], Todd A. Gaines[3], Aldo Merotto[1]; [1]Federal University of Rio Grande do Sul, Porto Alegre, Brazil, [2]Federal University of Rio Grande do Sul, Fort Collins, Brazil, [3]Colorado State University, Fort Collins, CO, [4]Corteva Agriscience, Porto Alegre, Brazil (068)

The herbicide florpyrauxifen-benzyl was recently released aiming to control quinclorac, ALS and ACCase resistant biotypes of *Echinochloa*. The objective of this study was to identify biotype of *E. crus-galli* resistant to florpyrauxifen-benzyl and its mechanism of resistance. 20 biotypes of *E. crus-galli* from Brazil that were never sprayed with florpyrauxifen-benzyl were screened with the label rate 30 g ha^{-1}. The most resistant biotype was selected with florpyrauxifen-benzyl for three generations. The resistant biotype and one susceptible were submitted to dose-response curves evaluating P450 (malathion) and GST (NBD-Cl) metabolic inhibitors in greenhouse (28ºC ± 3). The doses sprayed ranged from 0 to 240 g ha^{-1}. It was also performed dose-response curves for both biotypes under two different temperatures 35ºC/30ºC and 25ºC/20ºC day/night in growth chamber. The fresh shoot weight was evaluated, and the data fitted to three parameters log-logistic curve. The resistant biotype showed a resistance factor (RF) of 3.57 to florpyrauxifen-benzyl when compared to susceptible. The previous spray with P450 inhibitor reduced the RF to 1.49, while the GST inhibitor slightly reduced the RF to 2.51. When the dose-response curves were performed in 35ºC/30ºC the RF increased to 5.21, and for 25ºC /20ºC the RF was 2.37. It was identified a biotype with innate resistance to florpyrauxifen-benzyl by enhanced metabolization. RNA sequencing data analysis are being done. The metabolic resistance is a huge concern, due to ability to evolve to resistance to multiple herbicides, but lower temperatures can be an opportunity to manage this mechanism of resistance.

Evaluation of Dichlorprop-p for Management of Resistant Kochia in Fallow and Small Grains. Daniel Beran*[1], Bob Bruss[2]; [1]Nufarm Americas, Eldora, IA, [2]Nufarm Americas, Morrisville, NC (069)

Dichlorprop-p is a group 4 phenoxy herbicide developed by Nufarm that has recently shown potential for the management of herbicide resistant plants. Duplosan, an ester formulation containing 4 lbs. ae/gal of dichlorprop-p, has been used under a special local need label in Texas for post-harvest crop destruction of cotton including 2,4-D tolerant varieties. This efficacy on 2,4-D tolerant cotton led to the evaluation of dichlorprop-p on 2,4-D tolerant weeds. Efficacy studies conducted from 2019-2021 have indicated promising levels of control of kochia (*Bassia scoparia*), including biotypes resistant to 2,4-D, dicamba, fluroxypyr and glyphosate. Scorch EXT, a premix combination of dichlorprop-p, dicamba and 2,4-D was registered in 2020 for noncropland use and is pending registration for fallow and preplant usage. Kochia efficacy trials in fallow were conducted with Scorch EXT in 2020-2021 in KS, NE and MT. Spring applied Scorch EXT at 24 fl. oz./A (0.5 lbs. dichlorprop-p + 0.25 lbs. 2,4-D + 0.25 lbs. dicamba) provided between 84-99% control of kochia when evaluated 50-60 days after application. Dichlorprop-p plus bromoxynil is also being developed as an in-crop wheat and barley herbicide. In 2021 field trials conducted in MT, SD, and ND , the combination of 0.5 lbs./A dichlorprop-p plus 0.25 lbs./A bromoxynil applied postemergence in wheat or barley provided excellent activity on kochia, averaging 96% control at 30 days after application. Further studies in small grains have indicated that dichlorprop-p has excellent crop safety and good compatibility with the grass herbicides, pinoxaden, flucarbazone, and fenoxaprop-p-ethyl.

Utilization of Pre-emergent Oxyfluorfen to Control Weedy (Red) Rice (*Oryza Sativa Spontanea*), an Emerging Chemical Control Option for California Rice Producers. Liberty B. Galvin*, Kassim Al-Khatib; University of California, Davis, CA (070)

There are currently no chemical control options for weedy (red) rice (*Oryza sativa spontanea*), a concerning pest in California rice systems. ROXY rice is oxyfluorfen-tolerant and will be available to California rice growers within a few years. Field trials occurring at the Rice Experiment Station in Biggs, CA, suggest that oxyfluorfen provide exceptional weed control of common rice-field weeds. These field trials did not contain weedy rice, however, so it was unknown as to whether oxyfluorfen would provide adequate control of weedy rice. The objective of this experiment was to determine if pre-emergent applications of oxyfluorfen could be a viable control option for weedy rice. The experiment was conducted in a greenhouse facility on UC Davis campus. Weedy rice types 1, 2, 3, and 5 as well as M206, a common California cultivar, were planted at 1.3- and 2.5-cm soil depths. Oxyfluorfen was applied to the soil in pre-emergent application rates of 0, 0.56, 1.12, 2.24, and 4.5 kg ai/hectare within a 187 L/hectare applicate volume. Necrosis was selected to represent visual injury ratings. Total emergence was recorded daily for the duration of the 28-day experiment. All rice types successfully emerged from all treatments; total emergence was the highest in pots treated with 0.56 kg ai/hectare. All plants, regardless of rate, type, or burial depth, were completely necrotic by the end of the experiment. Results suggest that oxyfluorfen could be used as a pre-emergent chemical control option for weedy rice in California.

The Stale-drill Cropping Method in California Rice: Challenges and Potential for Small-grain Systems. Alex R. Ceseski*, Kassim Al-Khatib; University of California, Davis, CA (071)

The California rice industry faces many challenges, most notably water availability, strong flood-adapted weed pressure, limited herbicide availability, and widespread herbicide resistance. Various alternative methods of stand establishment -as well as water and herbicide management- exist to address these issues singly, but there are not many tools available to address them together. We have been developing a new cropping strategy for California rice that incorporates two uncommon practices for weed control and stand establishment, which has the potential to be a viable rotational option for some growers: the "stale-drill" method. Stale-drill rice cropping combines a stale seedbed with deep drillseeding to permit a safe burndown application of nonselective herbicides to early-emerging weeds, just prior to stand emergence. This method allows the use of novel modes of action on weeds that may be resistant to existing rice herbicides, while avoiding planting delays that a traditional stale seedbed requires. We have found that California rice cultivars possess suitable seedling vigor to emerge rapidly and evenly from seeding depths of up to 6cm, under favorable conditions. Using glyphosate as a postplant-preemergent burndown (PPB) treatment, timed to the date of first observed rice emergence, we are able to control 50-90% of grasses, while avoiding lasting crop injury. We also found that using flush-irrigation for the first 30-40 days of the season provided adequate water for rapid rice stand growth, yet suppressed the growth of algae, broadleaf weeds, ricefield bulrush, and late watergrass. This method can also result in yields competitive with standard water-seeded rice practice. Under less-favorable conditions, however, we found that rice emergence can be delayed by low temperatures and overly damp soils. Delaying rice emergence under these conditions can result in uneven emergence, as well as reduced rice stand density and vigor. As PPB treatment is timed to rice stand emergence, delaying treatment in this manner can allow competitive grass weeds to grow too large or dense to control adequately, creating conditions for reduced rice competitiveness, as well as potentially causing significant rice injury. This novel rice cropping method will continue to be studied and refined, as the parameters for favorable conditions for this method are determined. The stale-drill method may also present interesting research opportunities in other small-grain cereals.

Evaluation of CoAXium Winter Wheat Varietal Tolerance to Quizalofop in the Southern Great Plains. Caitlyn Carnahan*[1], Misha R. Manuchehri[1], Brett Carver[1], Vipan Kumar[2], Hannah C. Lindell[1], Lane S. Newlin[1], Justin T. Childers[3]; [1]Oklahoma State University, Stillwater, OK, [2]Kansas State University, Hays, KS, [3]Oklahoma State University, Marlow, OK (072)

CoAXium Wheat Production Systems offers postemergence control of many annual grass weeds. However, in the state of Oklahoma, crop tolerance concerns have been raised by agricultural stakeholders. To evaluate the response of winter wheat varieties that contain the AXigen trait, a study was conducted at Perkins and Tipton, Oklahoma and Hays, Kansas. Varieties included AP18, Crescent, Fusion, Helix, and Photon. Two herbicide treatments, 1X rate (92 g a.i. ha^{-1} of quizalofop-P-ethyl plus MSO at 1% vol/vol) and 2X rate (185 g a.i. ha^{-1} of quizalofop-P-ethyl plus MSO at 2% vol/vol) were applied at three timings: fall (three to five-leaf wheat), early spring (first hollow stem), and late spring (second node detectable). The 2X rate was only applied in the 2021-2022 season. For the 2020-2021 growing season, at peak visual injury, AP18 exhibited the highest level of damage of 17%, 22%, and 51% at Hays, Perkins, and Tipton, respectively. When evaluating grain yield, a herbicide application timing effect was present at all locations. The early spring timing reduced yield up to 9% when compared to the other timings and nontreated at Perkins. At Tipton, a similar trend was observed, where the early spring timing resulted in 9% yield reduction compared to the fall. At Hays, the late spring application reduced yield 16%, 7%, and 11% compared to nontreated, fall, and early spring timings, respectively. At Perkins for peak visual injury for the 2021-2022 growing season, AP18 exhibited the highest damage (72%) across both rates. A herbicide rate effect was observed at Tipton where the 2X rate resulted in an average of 16% more injury than the 1X rate. Lastly, a variety by herbicide rate effect was observed at Hays. The 2X rate applied to Crescent and Fusion resulted in ~80% injury, while Fusion and Helix were only injured ~41%.

Efficacy and Crop Safety of a New Cross Spectrum Herbicide Premix Containing Pinoxaden, Halauxifen-methyl and Fluroxypyr-meptyl, in Northern Plains and Pacific Northwest Cereals. Joe Yenish*[1], Patti Prasifka[2], Dave Johnson[3], Mike Moechnig[4], Ryan Humann[5]; [1]Corteva

Agriscience, Billings Metropolitan Area, MT, [2]Corteva Agriscience, West Fargo, ND, [3]Corteva Agriscience, Eagan, MN, [4]Corteva, Toronto, Canada, [5]Corteva Agriscience, Fargo, ND (073)

Rezuvant® herbicide is a novel premix formulation of an ACCase inhibiting herbicide, pinoxaden (HRAC Group 1) and two synthetic auxin (HRAC Group 4) herbicides, halauxifen-methyl and fluroxypyr-meptyl. It is labeled for use in wheat (excluding durum) and barley. At its single labeled use rate of 16.4 fl. oz. per acre, Rezuvant delivers 60 grams pinoxaden, 125 g fluroxypyr, and 5 g halauxifen per hectare. The unique and convenient Rezuvant emulsifiable concentrate formulation contains both a safener and a built-in adjuvant. Field research was conducted during the 2018, 2019, 2020, and 2021 cropping seasons at multiple locations across the U.S. Northern Plains and Pacific Northwest to evaluate the efficacy of Rezuvant on various grass and broadleaf weeds, along with crop safety when applied post-emergence in spring cereals. It was applied alone and with various synthetic auxin or ALS-inhibiting (HRAC Group 2) herbicides. Rezuvant provided excellent activity against redroot pigweed (*Amaranthus retroflexus*), common lambsquarters (*Chenopodium album*), kochia (*Bassia scoparia*) and other broadleaf weed species. Moreover, it provided excellent control of wild oats (*Avena fatua*), green foxtail (*Setaria viridis*), yellow foxtail (*Setaria pumila)*, Persian darnel (*Lolium persicum*), and Italian ryegrass (*Festuca perennis*). There was little to no crop response on spring cereals with Rezuvant alone or with tank mix partners, indicating excellent crop safety. Grass activity of Rezuvant was not reduced when tank mixed with MCPA, clopyralid, or thifensulfuron plus tribenuron. Rezuvant will provide cereal growers with an excellent cross-spectrum tool to control key grass and broadleaf weeds in cereal production systems. ™® Trademarks of Corteva Agriscience and its affiliated companies.

Germination Response of Italian Ryegrass (*Lolium multiflorum*) to Gibberellic Acid 3 and Preemergence Herbicides in Eastern Washington Dryland Wheat Production. Madisyn R. Beaudoin[1], Rachel J. Zuger[2], Samuel R. Revolinski[1], Ian C. Burke*[1]; [1]Washington State University, Pullman, WA, [2]Washington State Univeristy, Pullman, WA (074)

Italian ryegrass (*Lolium multiflorum*) is a winter annual grass currently plaguing the dryland wheat production systems of the Pacific Northwest (PNW). Italian ryegrass populations in the PNW have developed resistance to most herbicides used to manage it. Gibberellic acid (GA_3) is a plant growth hormone that alleviates dormancy in seed, and its potential as a weed seedbank management tool is appealing. A study was conducted near Pullman, WA in 2020 and 2021 to assess the response of Italian ryegrass seedbanks to applications of GA_3 alone and in combination with herbicide systems for Italian ryegrass management. Gibberellic acid was applied preemergence to winter wheat alone and in mixture with pyroxasulfone, flumioxazin plus pyroxasulfone, or flumioxazin plus pyroxasulfone plus metribuzin, followed by postemergence spring treatments of pinoxaden. Italian ryegrass densities and biomass were assessed in the spring after all treatments were applied. Italian ryegrass control in winter wheat was greatest when preemergence applications of pyroxasulfone or flumioxazin plus pyroxasulfone plus metribuzin were followed by postemergence applications of pinoxaden. However, the addition of GA_3 did not improve Italian ryegrass control. Additional experiments are needed to determine the impact of soil temperature and precipitation on the efficacy of GA_3 for seedbank management.

Herbicide Strategies for Grass and Broadleaf Weed Control in Spring Wheat in the Northern Great Plains. Het S. Desai*; Montana State University, Bozeman, MT (075)

Due to the escalating cases of multiple herbicide-resistant weed biotypes selection, diversification of herbicide application is recommended to delay gene alteration, hence herbicide resistance. However, there is limited knowledge about mixing herbicides in spring wheat for the Northern Great Plains available. Our field trials at two different locations (Huntley and Kalispell) in Montana in summer 2021 showed that two-pass herbicide strategies (PRE followed by POST) provided better control over kochia and wild oats compared to one-pass (only PRE or POST). Two two-pass herbicide strategies, such as glyphosate + saflufencil *fb* pinoxaden and pendimethalin *fb* pinoxaden proved to be the foremost in controlling kochia and wild oats at both research sites. In Huntley, two-pass strategies, such as glyphosate + pyroxasulfone *fb* pinoxaden and pyroxasulfone + carfentrazone-ethyl *fb* pinoxaden provided >95% and 100% control over kochia and wild oats, respectively; however, other minor weed species from exiting seedbank, such as downy brome, Russian thistle, and wild buckweed, were able to produce negligible biomass. In Kalispell, two-pass strategies, such as glyphosate + pyroxasulfone *fb* pinoxaden and pyroxasulfone + carfentrazone-ethyl *fb* pinoxaden, displayed 100% control over kochia and wild oats; however, some other weed species, such as lambsquaters and pennycress, survived and produced trivial biomass. Regardless of its one-pass nature, pyrasulfotole + bromoxynil octanoate + bromoxynil heptanoate + pinoxaden, provided 100% control at both research sites. No crop phytotoxicity was observed at both research sites; therefore, herbicide strategies did not influence grain yield. Farmers could directly adopt herbicide strategies explored in this research to manage kochia and wild oats in spring wheat in Northern Great Plains. Next year, we plan to repeat this research at both locations to assess the seasonal variations.

Seedbank Management of Italian Ryegrass (*Lolium multiflorum*) in High Rainfall Zones of Eastern Washington. Kenton C. Lyman*, Samuel R. Revolinski, Ian C. Burke; Washington state University, Pullman, WA (076)

Italian ryegrass (*Lolium multiflorum*) is a problematic weed in the wheat production regions of the inland Pacific Northwest (PNW). Preemergence herbicides are used widely to manage Italian ryegrass, but little is known of the yearly changes in populations in response to common PNW rotations and management tactics. The objective of the study is to evaluate the effect of crop rotations and indaziflam on Italian ryegrass populations in eastern Washington. Two studies with a randomized complete block design and 4 replications was initiated the spring of 2020, near Almota, and Pullman, WA. Three main plot treatments were applied (pinoxaden alone, indaziflam at 22 g ai/ha plus pinoxaden, or indaziflam at 44 ga ai/ha plus pinoxaden) were applied to spring wheat. In year 2, main plots were split into 5 sub plots and dryland rotational small grain and broadleaf crops were planted. Due to a prolonged and significant drought in 2021, overall Italian ryegrass densities were low, and there was no effect of 2021 crop rotation or herbicides applied in 2020. Indaziflam caused significant crop injury to winter wheat planted in the fall of 2020, but barley, canola, and chickpea were not affected when planted in the spring of 2021. Winter wheat was planted in the fall of 2021, and was not affected by indazifalm applied in 2020. While drought impacted year over year assessments of Italian ryegrass populations, indaziflam does appear to be a safe treatment when used at relatively low rates in annual rotational crops in the PNW.

New Herbicide-Resistant Grain Sorghum for Grass Weed Control in High Plains. Vipan Kumar*[1], Rui Liu[1], Sachin Dhanda[1], Taylor Lambert[1], Brent Bean[2]; [1]Kansas State University, Hays, KS, [2]United Sorghum Checkoff, Lubbock, TX (077)

Lack of over-the-top herbicide (POST) options for grass weed control is a serious challenge in grain sorghum. Recent development and commercialization of three different sorghum hybrids with tolerance to imazamox (Igrowth™), nicosulfuron (Inzen™), and quizalofop-p-ethyl (Double Team™) will allow growers to use these respective herbicides for in-season control of grass weeds. The main objective of this research was to determine the effectiveness of various herbicide programs for grass weed control in these new herbicide-resistant (HR) sorghum technologies. Three HR grain sorghum hybrids viz. Igrowth™, Double Team™, and Inzen™ were separately planted in field experiments during 2021 growing season at Kansas State University Agricultural Research Center near Hays, KS. The field site had natural infestation of green foxtail. Each field experiment was conducted in a randomized complete block design with 4 replications. Among all programs tested in Igrowth™ sorghum, PRE alone treatment of imazamox at 78 g ha^{-1} and PRE applied s-metolachlor *fb* a POST treatment of imazamox tested at both rates provided an excellent control (85 to 93%) of green foxtail up to 7 weeks after PRE (WAPRE) or 4 weeks after POST (WAPOST), whereas control did not exceed more than 58% with PRE alone treatments of s-metolachlor or s-metolachlor + atrazine. In Double Team™ sorghum, PRE applied atrazine or atrazine + s-metolachlor *fb* a POST treatment of quizalofop-p-ethyl alone or in combination with dicamba provided 91 to 95% green foxtail control at 7 WAPRE (4 WAPOST). Tank-mixing 2,4-D with quizalofop-p-ethyl had reduced activity on green foxtail (72% control). In Inzen™ sorghum, PRE applied atrazine or atrazine + s-metolachlor *fb* a POST treatment of nicosulfuron alone or in combination with 2,4-D provided 86 to 90% green foxtail control at 7 WAPRE (4 WAPOST). In a separate greenhouse study, POST applied quizalofop-p-ethyl, clethodim, and nicosulfuron provided excellent control (87 to 100%) of southwest cupgrass, prairie cupgrass, and giant foxtail; whereas, control of these weed species was inadequate with POST applied imazamox. These results suggest that newly developed HR sorghum technologies (Igrowth™, Inzen™, and Double Team™) provide effective herbicide options for controlling green foxtail, southwest cupgrass, prairie cupgrass, and giant foxtail; however, the effectiveness of imazamox in Igrowth™ sorghum will be species dependent.

Sweep Tillage Impact on Tumble Windmill Grass. Grace F. Flusche Ogden*, Jason G. Warren; Oklahoma State University, Stillwater, OK (078)

Tumble windmill grass (*Chloris verticillata)* is a native, perennial grass of the United States that is a growing problem in no-till production, as it is difficult to control with herbicides once established. Sweep tillage is a form of conservation tillage that could effectively control tumble windmill grass populations while retaining benefits of no-tillage, such as soil surface residue and soil moisture retention. Sweep tillage is performed with a V-shaped blade that undercuts the top 7-10 cm of soil. Two studies were initiated during the fallow period prior to planting and throughout the 2020 and 2021 growing seasons in winter wheat cropping systems near Stillwater, Oklahoma in 2020 and Wakita, Oklahoma in 2021 to investigate sweep tillage control of tumble windmill grass. The objective of the first study, Sweep-Disk-Chem, was to determine the efficacy of chemical-only control of tumble windmill grass as compared to intensive tillage alone (disk) and conservation tillage combined with chemical control (sweep + herbicide). The objective of the second study, Prolonged Sweep, was to assess one, two, or three passes of sweep in one season on tumble windmill grass control. Control of tumble windmill grass during fallow prior to planting was similar among treatments in both years. After crop emergence tillage treatments had greater tumble windmill grass control than chemical-only treatments in both years. This trend continued for the duration of the season. These studies suggest that sweep tillage could offer the opportunity to effectively control tumble windmill grass while retaining benefits that aid in soil health.

Herbicide Programs for Control of Palmer Amaranth (*Amaranthus palmeri*) in Dry Bean. Joseph T. Ikley*, Nathan H. Haugrud; North Dakota State University, Fargo, ND (079)

Herbicide-resistant Palmer amaranth (*Amaranthus palmeri*) has been introduced into several counties in the Northarvest Bean Growers region, which encompasses North Dakota and Minnesota. Annual survey results indicate that waterhemp and redroot pigweed are amongst the worst weeds in dry bean hectares in the Northarvest Bean Growers region. Palmer amaranth populations detected in North Dakota are resistant to ALS-inhibiting (Group 2) herbicides, which is of particular concern due to heavy grower reliance on using imazamox in their herbicide programs in dry beans. Two trials were conducted in 2021 to evaluate herbicide programs for control of ALS-inhibitor resistant Palmer amaranth. All field experiments were conducted in Barnes county ND, conventionally tilled, and were conducted as RCBD with four replications. The first experiment was comprised of 16 treatments applied either PPI or PRE. Palmer amaranth control ratings were evaluated every two weeks for eight weeks after planting. PPI-applied treatments: EPTC, ethalfluralin, pendimethalin, EPTC + ethalfluralin, sulfentrazone & *S*-metolachlor, and sulfentrazone & carfentrazone + pendimethalin provided the greatest control of Palmer amaranth at 8 weeks after planting. The second experiment evaluated 12 different POST herbicide programs for control of Palmer amaranth. EPTC + ethalfluralin were applied PPI, and POST treatments were applied to 5-cm Palmer amaranth, with 6 treatments receiving a planned sequential application of the same herbicides products and rates 7 days after initial treatment. Plots were evaluated for crop injury and weed control 7, 14, and 28 days after initial POST treatment. A single application of fomesafen (210 g ha^{-1}) or bentazon + fomesafen (1120 + 210 g ha^{-1}), or sequential applications of bentazon + fomesafen (560 + 105 g ha^{-1} fb 560 + 105 g ha^{-1}), or bentazon + fomesafen + imazamox (560 + 105 + 17.5 g ha^{-1} fb 560 + 105 + 17.5 g ha^{-1}) provided the greatest Palmer amaranth control. These trials all provide insight into herbicide programs that can currently be used in conventionally-tilled dry bean to control herbicide-resistant Palmer amaranth. The trials will be repeated in 2022 to provide a second year of data on the utility of these herbicides to control ALS-inhibitor resistant Palmer amaranth.

Palmer Amaranth Interference and Fecundity in Dry Bean. Joshua W.A. Miranda*[1], Amit J. Jhala[2], Jeff Bradshaw[3], Nevin Lawrence[3]; [1]Oregon State University, Corvallis, OR, [2]University of Nebraska-Lincoln, Lincoln, NE, [3]University of Nebraska-Lincoln, Scottsbluff, NE (080)

Palmer amaranth arrived in Western Nebraska around 2014 and is becoming a common weed in the region. Palmer amaranth is still spreading further north and west, with recent observations in Canada, North Dakota, and Wyoming. Palmer amaranth interference and fecundity in dry bean has never been studied before. The objective of this field study was to quantify the impact of season-long Palmer amaranth interference on dry bean yield and quality, and the fecundity of Palmer amaranth. This study was conducted in Scottsbluff, NE during the growing seasons of 2020 and 2021. Palmer amaranth interference was evaluated at fixed densities of 0 (weed-free control), 0.2, 0.3, 0.5, 1, and 2 plants m^{-1} row. Palmer amaranth interference reduced dry bean yield 77% at a density of 2 plants m^{-1} row; and a 5% yield-reduction threshold was estimated to occur at 0.02 Palmer amaranth plants m^{-1} row. A reduction in the number of pods $plant^{-1}$ as Palmer amaranth interference density increased was the largest crop yield component contributing to total dry bean yield reduction. Palmer amaranth plants produced between 91,000 to 376,000 seeds $plant^{-1}$ depending on densities, and as many as 140,000 seeds m^{-2}. Dry bean is more sensitive to Palmer amaranth interference compared to corn, soybean, or peanut. Results will help farmers and other stakeholders estimate Palmer amaranth interference within their fields to aid in making management decisions, and may also help in the adoption of best herbicide-resistant management practices with a focus on a long-term management of the soil seedbank.

Cover Crop and Herbicide Combinations for Season-Long Weed Control in Dry Beans. Ryan T. Johnson*[1], Jenna Meeks[2], Charles Tyler Hicks[3], Andrew R. Kniss[1]; [1]University of Wyoming, Laramie, WY, [2]University of Wyoming, Torrington, WY, [3]University of Wyoming, Powell, WY (095)

Herbicides remain an important weed management tool in dry edible beans but reducing reliance on herbicides through integrated weed management practices is important. The objective of this study was to evaluate the effect of cover crops in combination with herbicide applications on weed suppression in dry bean. If cover crops effectively suppress weeds, reliance on herbicides may be reduced and economic benefits may be possible. Field studies were conducted in 2021 near Lingle and Powell, WY. A small grain cover crop (winter wheat) was planted in March (early) and in April (late), with a control treatment of no cover crop. Pinto beans were planted in early June and the cover crop was terminated with glyphosate on the day of planting. Each cover crop whole-plot was divided into four split-plots consisting of the following herbicide treatments: no herbicide, preemergence (PRE) herbicide application only (pendimethalin + dimethenamid-P), postemergence (POST) herbicide application only (bentazon + imazamox), and sequential PRE and POST herbicide applications. Small grain biomass at time of bean planting was greater in Lingle (3,669 kg/ha) compared to Powell (594 kg/ha). Cover crops reduced kochia density by an average of 73% at Lingle and 49% at Powell compared to the no cover crop treatment. POST herbicide had a greater impact on protecting dry bean yield than PRE herbicides or cover crops. The use of cover crops combined with herbicides provided weed suppression and yield benefits in dry beans.

TENDOVO - Setting the Standard for Soybean Herbicides. Stott Howard*[1], Pete Eure[2], Brett R. Miller[3]; [1]Syngenta Crop Protection, Des Moines, IA, [2]Syngenta Crop Protection, Greensboro, NC, [3]Syngenta Crop Protection, Fargo, ND (096)

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

Effect of Winter Wheat Cover Crop Termination Time on Dry Bean Production. Tyler C. Hicks*[1], Andrew R. Kniss[2], David A. Claypool[2]; [1]University of Wyoming, Fort Collins, CO, [2]University of Wyoming, Laramie, WY (097)

Direct harvest of dry edible beans is becoming more common in Wyoming and Western Nebraska. Cover crops are often promoted for weed suppression, and past research has shown that the presence of a cover crop increases dry bean node and pod heights. The objective of this study was to evaluate the effect of cover crop termination timing on dry bean pod height, yield, and direct harvest yield loss. Field studies were conducted in 2019 and 2020 near Lingle, Wyoming. Beans were planted directly into a winter wheat cover crop which was terminated at different times ranging from 30 days before planting to 28 days after planting. The experimental design was a split-plot treatment arrangement of winter wheat termination timing (whole-plot) and bean variety (split-plot) set in a randomized complete block design with 8 replicates. There is a window for cover crop termination to effect harvest efficiency without negatively impacting bean yield between 2 and 10 days after planting. However, there are extra costs when planting and terminating a cover crop. A partial budget was created to compare a conventional bean production system, direct harvest system, and a direct harvest system with a cover crop. Addition of a cover crop to the direct harvest system increases costs, but these costs may be offset if cover crops can be shown to provide sufficient weed suppression to reduce herbicide costs.

Weed Control Efficacy and Dry Bean Response to Preemergence Herbicide Activation Timing. Albert T. Adjesiwor*, James Gomm, Howard Neibling; University of Idaho, Kimberly, ID (098)

A field experiment was conducted in 2021 to evaluate the effect of irrigation timing on EPTC, flumioxazin, pyroxasulfone, and flumioxazin plus pyroxasulfone weed control efficacy and safety in dry bean (*Phaseolus vulgaris*). There were 14 treatments arranged in a randomized complete block with four replications. Treatments comprised of a weedy and hand-weeded check, and EPTC (3,430 g ai ha^{-1}), flumioxazin (53.6 g ai ha^{-1}), pyroxasulfone (119 g ai ha^{-1}), and flumioxazin + pyroxasulfone (70.4 + 89.3 g ai ha^{-1}) incorporated with overhead irrigation at 1, 4, and 8 days after herbicide treatment (DAT). At 31 days after preemergence herbicide application, common lambsquarters (*Chenopodium album*) control was 64 to 75% (EPTC), 65 to 78% (flumioxazin), 60 to 63% (pyroxasulfone), and 70 to 83% (flumioxazin + pyroxasulfone). Redroot pigweed (*Amaranthus retroflexus*) control was 50 to 78% (EPTC), 58 to 66% (flumioxazin), 65 to 77%

(pyroxasulfone), and 79 to 87% (flumioxazin + pyroxasulfone). Hairy nightshade (*Solanum physalifolium*) control ranged from 63 to 83% (EPTC), 66 to 74% (flumioxazin), 71 to 79% (pyroxasulfone), and 76 to 87% (flumioxazin + pyroxasulfone). Delaying activation irrigation until 8 DAT reduced EPTC efficacy by 3 to 28%. Delaying flumioxazin activation irrigation until 8 DAT slightly reduced dry bean stand density early in the season but the crop recovered thereby reducing the impact of the herbicide injury on dry bean yield. Seed yield was 320 kg ha^{-1} in the weedy check and 2,746 to 4,275 kg ha^{-1} in herbicide-treated plots which were statistically similar to the hand-weeded check.

Effect of Fall- or Spring-Planted Cover Crops on Weed Suppression in the Central Great Plains. Sachin Dhanda*[1], Vipan Kumar[1], Rui Liu[1], Taylor Lambert[1], Augustine Obour[1], Anita Dille[2]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Manhattan, KS (099)

The widespread evolution of herbicide resistance in kochia and Palmer amaranth (two key weed species) warrants the development of alternative, ecological-based integrated weed management (IWM) strategies in the Central Great Plains (CGP). Two separate field experiments were conducted at Kansas State University Agricultural Research Center near Hays, KS in 2020 to determine the effect of fall- and spring-planted cover crops (CC) on kochia and Palmer amaranth suppression (density and biomass reduction). A CC mixture (triticale/winter peas/radish/rapeseed) was planted during fall after wheat harvest and terminated at triticale heading stage in spring with glyphosate and/or glyphosate + (acetochlor + atrazine). Spring-planted CC mixture (oats/spring peas/barley) was planted in sorghum stubble and terminated at oats heading stage with glyphosate and/or glyphosate + (flumioxazin + pyroxasulfone). Chemical fallow plots were included for comparison. Total weed density and weed biomass were recorded using two 1-m^2 quadrats from each plot at monthly intervals. Fall-planted CC terminated with glyphosate + (acetochlor + atrazine) reduced weed density by 98 and 95% at termination and 30 days after termination (DAT), respectively and reduced total weed biomass by 73% at sorghum harvest as compared to chemical fallow. Spring-planted CC terminated with glyphosate + (flumioxazin + pyroxasulfone) provided complete weed suppression at termination and 43 to 77% suppression at 40 DAT compared to chemical fallow. These results suggest that fall- and spring-planted CC in combination with residual herbicide at termination can serve as an important IWM strategy for managing HR kochia and Palmer amaranth in the semiarid CGP region.

Better Together: Bicyclopyrone and Mesotrione Enhance Weed Control in Acuron GT. Pete Forster*[1], Ryan D. Lins[2], Mark Kitt[3], David Stafford[4], Mark Johnston[4], Brian Pickett[4], Sunil Kumar[5]; [1]Syngenta Crop Protection, Eaton, CO, [2]Syngenta Crop Protection, Rochester, MN, [3]Syngenta Crop Protection, Greensboro, NC, [4]Syngenta Crop Protection, Jealotts Hill, United Kingdom, [5]Syngenta Crop Protection, Basel, Switzerland (100)

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

Inter-seeded Cover Crop Performance for Competitive Suppression of Weeds and Invasive Kochia in Small Grains Crops in the Intermountain West. Dani Thiemann*[1], Corey V.

Ransom[2], Earl Creech[2]; [1]Utah State University, Nibley, UT, [2]Utah State University, Logan, UT (101)

In irrigated crop systems, consideration of inter-seeded cover crops and other management methods is critical to successful control of annual weeds including kochia [*Bassia scoparia* (L.) A.J. Scott]. Field studies were conducted in Utah to determine effective integrated weed management (IWM) for the suppression of kochia and other weeds in small grain crops. Integrated weed management tactics were tested by varying planting dates (early; late), seeding rate (100lbs/A; 150lbs/A) with applications of herbicide alone (pyrasulfotole + bromoxynil) and in combination with inter-seeded cover crops (MCPA; *Trifolium pratense*). Suppression of weed biomass was accomplished through the integration of early plantings at a higher seeding rate and through the application of cover crops and herbicides, alone and in combination. Cover cropping provided weed control similar to singular applications of pyrasulfotole + bromoxynil. This demonstrates that cover crops, such as clover, could become another option in an IWM approach for weed management in irrigated cropping systems of the Western US. However, less success was found in further field studies conducted to identify optimal cover crops type and seeding rate. Most tested covers across all seeding rates poorly established likely due to drought conditions. Inter-seeded hairy vetch [*Vicia villosa*] however established though due to its vining nature interfered with harvest making this an unsuitable candidate for inter-seeded cover though it has historically good performance as a rotational cover crop. Further studies are needed to identify the efficacy of inter-seeded cover cropping in an IWM approach, especially with varied abiotic factors.

Response of Conventional Grain Sorghum to Simulated Drift of Imazamox, Nicosulfuron, and Quizalofop-p-ethyl. Rui Liu*[1], Vipan Kumar[1], Sachin Dhanda[1], Monica R. Marrs[2], Taylor Lambert[1]; [1]Kansas State University, Hays, KS, [2]Kansas State University, Manhattan, KS (102)

Grass weed control is a serious challenge for sorghum growers. Three newly developed herbicide-resistant (HR) sorghum technologies, viz. Igrowth™, Inzen™, and DoubleTeam™ will allow the use of imazamox, nicosulfuron, and quizalofop-p-ethyl, respectively for in-season grass control. However, the adoption of these HR sorghum technologies in conjunction with increasing use of labelled herbicides will increase the likelihood of physical drift and/or tank contamination to nearby conventional sorghum. Three separate field experiments were conducted at Kansas State University Agricultural Research Center (KSU-ARC) near Hays, KS, to understand the response of conventional sorghum when exposed to various rates of imazamox, nicosulfuron, and quizalofop-p-ethyl (QPE) herbicides at two different growth stages. Experiments were conducted in a randomized complete block design with four replications. Six rates of imazamox, nicosulfuron, and quizalofop-p-ethyl, including 1/200X, 1/100X, 1/50X, 1/25X, 1/2X, and 1X (field-use rates of imazamox = 53 g ha^{-1}, nicosulfuron = 70 g ha^{-1}, and quizalofop = 73 g ha^{-1}) were separately tested at two different growth stages of sorghum (3- to 5-leaf stage and flag leaf stage). Data on sorghum visual injury (%) were collected at biweekly intervals and sorghum biomass and grain yield at harvest. Results indicated that the field-use rates (1X) of imazamox, nicosulfuron, and quizalofop resulted in 90 to 100% injury and complete or near-complete grain yield loss regardless of application timings. Furthermore, the dose-response analysis predicted that 32 to 52 g ha^{-1} of imazamox, 1.2 to 1.6 g ha^{-1} of nicosulfuron, and 20 to 23 g ha^{-1} of quizalofop were needed for 90% grain yield loss across two application timings. In conclusion, these results suggest that either tank contamination or physical drift of these herbicides (even at low rates) can cause complete or near-complete loss of non-HR sorghum. Growers adopting these new HR technologies should be proactive and follow proper stewardship guidelines to avoid the drift/tank contamination from these herbicides to non-HR sorghum.

Incorporating Cover Crops into a Semi-arid Alfalfa Rotation: Yield, Weed Control, and Economic Considerations. Tyler Z. Jones*, Brian A. Mealor; University of Wyoming, Sheridan, WY (119)

Cover cropping has received a great deal of attention in temperate agro-ecosystems throughout the world. While the practiced is publicized for its ability to improve the soil microbiome, increase cash crop yields, and reduce weed competition, cover cropping effects are not well understood in semi-arid regions (<500mm precipitation). Wyoming producers have expressed interest in incorporating cover crops into their hay/livestock operations, but literature regarding these applications is scarce. We compared forage productivity, weed response, and financial impacts between a diverse cover crop mix and a commonly-used forage barley under no-till and conventional tillage regimes in irrigated and dryland locations. We also assessed seedling alfalfa establishment and production under each regime. Cover crops and forage barley produced similar yields at each location ($p<0.05$) while differences in weed biomass ($p=0.0106$) and cover ($p=0.0272$) were observed only under irrigation and tillage. On dryland, cover cropping reduced bare ground regardless of tillage regime while bare ground was reduced under irrigation when either crop treatment was paired with no-till. Production costs were lower with both crops when using no-till. While forage barley typically yielded greater profits, dryland cover cropping was often profitable when supplemented by NRCS-EQIP payments. Irrigated cover crops almost always yielded positive net revenues. Planting a diverse cover crop in semi-arid alfalfa hay-field rotation yielded few detectable differences when compared to the standard approach of an annual forage grain.

Postemergence Herbicides for Broadleaf Weed Control in Sesame: the Good, the Bad, and the Ugly. J Connor Ferguson*[1], Eric Votava[2], Gerald De La Fuente[3], Zachary A. Carpenter[4]; [1]Sesaco Corporation, Yukon, OK, [2]Sesaco Corporation, Austin, TX, [3]Sesaco Corporation, San Antonio, TX, [4]Oro Agri Inc., New Braunfels, TX (120)

Sesame (*Sesamum indicum* L) is an annual dicotylendous species grown across the cotton belt in the United States, comprising of approximately 500,000 hectares each year. Sesame hectares are primarily (over 85%) in Oklahoma, Texas, and Kansas with other production in the southwest, mid-south, and south-eastern United States. Weed management in sesame is difficult due to the few number of herbicides labeled for use. Current preemergence herbicides labeled for use include *S*-metolachlor, trifluralin, and ethalfluralin with labeled post-directed options of prometryn and carfentrazone. Grass weed control is aided with labeled herbicides clethodim, quizalofop p-ethyl, and sethoxydim. There are no labeled broadleaf weed control herbicides for postemergence use in sesame. Field studies from 2019 through 2021 assessed potential postemergence broadleaf herbicide use in sesame and found varying results. Group 7 photosystem II inhibiting herbicides appear the most promising for postemergence broadleaf weed control in sesame – if applied at the right crop growth stage. HPPD inhibiting herbicides resulted in little injury when applied preemergence, but near complete plant death when applied postemergence. PPO inhibiting herbicides varied from low observed injury to more than 40% visual injury on sesame. ALS inhibiting herbicides also varied, resulting in low observed injury to near total plant death. EPSP synthase and glutamine synthetase inhibiting herbicides cannot be applied broadcast postemergence over sesame, but glutamine synthetase inhibiting herbicides show promise when applied post-directed or layby to sesame. From the nearly 70 herbicide active ingredients tested, sesame showed good tolerance to a majority of them (60%), little tolerance to a quarter of them (25%), and no tolerance to the remaining 15%. Results from these studies will aid in the further selection and sought after labeling of the promising herbicides to aid sesame growers in reduced weed pressure especially from broadleaf weeds.

Residual and Postemergence Weed Control in Newly Established Alfalfa. Chandra L. Montgomery*[1], James Gomm[2], Nevin Lawrence[3], Albert T. Adjesiwor[2]; [1]University of Idaho, Moscow, ID, [2]University of Idaho, Kimberly, ID, [3]University of Nebraska-Lincoln, Scottsbluff, NE (121)

Annual weeds can impact the economics of alfalfa production by reducing forage yield, nutritive value or by contaminating hay. Field studies were conducted in Idaho and Nebraska in 2021 to evaluate the efficacy of pre-plant incorporated (PPI), postemergence, and residual herbicides on annual weeds in newly established non-glyphosate resistant alfalfa. There were 16 treatments (including the untreated control) arranged in a randomized complete block design with four replications. Alfalfa was harvested multiple times and data was collected on visible weed control (common lambsquarters [Chenopodium album], kochia [Bassia scoparia], redroot pigweed [Amaranthus retroflexus]), weed biomass, forage biomass, and nutritive value. Herbicide treatments affected all measured variables ($p < 0.05$). At first harvest, common lambsquarters, kochia, and redroot pigweed, control was 44, 54, 50%, respectively for EPTC applied PPI, and 23, 31, 36% for acetochlor applied early postemergence (after 80% emergence). EPTC followed by imazamox or imazamox + bromoxynil provided 86 and 96% common lambsquarters control, 79 and 91% kochia control, 87 and 96% redroot pigweed control which was statistically similar to postemergence application (at third trifoliate) of imazamox, imazamox + bromoxynil or acetochlor followed by postemergence herbicides. The application of paraquat and residual herbicides (pendimethalin, flumioxazin) after the first harvest further improved weed control. High weed density in the untreated and some herbicide treated plots increased weed biomass in forage (9 to 66%) and this reduced crude protein (2 to 6%) and increased the fiber concentration (2 to 5%). This in turn reduced the relative feed value (9 to 23).

Hemp Tolerance to Soil Herbicides Applied POST. Joseph Mettler*[1], Kirk A. Howatt[1], Mike Ostlie[2], Bryan Hanson[3]; [1]North Dakota State University, Fargo, ND, [2]North Dakota State University, Carrington, ND, [3]North Dakota State University, Langdon, ND (122)

No herbicides are currently labeled for use in industrial hemp (*Cannabis sativa* L.) produced for seed in the United States. Effective weed control is necessary when planting hemp for grain at the commercially recommended densities of 110 to 130 plants m^{-2}. Adequate control of weeds can increase seed yield by 35%, and can result in \$600 per hectare increase in net profits, compared to weedy fields. As more research becomes available, it is apparent that POST herbicides that effectively control broadleaf weeds result in too much visible hemp injury to pursue herbicide registration. Several PRE-herbicides have resulted in minimal hemp injury, but may not provide adequate weed control until canopy closure. In 2021, experiments were conducted in Fargo, Carrington, and Langdon, ND to evaluate hemp tolerance and yield to PRE-herbicides applied POST. Hemp cultivars X-59, Katani, CRS-1, and Vega were established in a randomized complete block design. A base layer of PPI trifluralin was applied followed by a POST application of acetochlor, s-metolachlor, pyroxasulfone, or dimethenamid when hemp had 3 to 4 leaf pairs. Averaged across locations, acetochlor, s-metolachlor, pyroxasulfone, and dimethenamid resulted in 14, 6, 11, and 7% visible hemp injury 7 days after application (DAA). Trifluralin alone resulted in less than 2% injury at all evaluations. All herbicides resulted in less than 5% hemp injury by 14 DAA. Katani and X-59 resulted significant in 2% greater hemp injury than CRS-1 at 7 DAA, but the difference would not be of practical relevance in hemp production. Seed yield was similar among herbicides and cultivars at Carrington and Langdon. At Fargo, seed yield was 440, 600, 725, and 863 for Katani, CRS-1, X-59, and Vega, respectively. Vega and X-59 seed yields were similar statistically, and greater than Katani. Vega seed yield was also greater than CRS-1. Katani, regardless of herbicide treatment, resulted in the lowest seed yield at the Fargo location. Hemp that only received the PPI trifluralin application and those that additionally received a delayed PRE resulted in 960 and 1110 kg ha^{-1} on average, respectively. No herbicide residue was detected in any of the seed samples at a detectable limit of 0.030 mg/kg.

Comparison of ACCase Inhibiting Herbicides for Use in Industrial Hemp. Milos Zaric*[1], Marija Savic[2], Greg Kruger[1], Sam E. Wortman[3], Kelly W. Bruns[1]; [1]University of Nebraska-Lincoln, North Platte, NE, [2]Washington State University, Pullman, WA, [3]University of Nebraska-Lincoln, Lincoln, NE (123)

Considering that Acetyl CoA Carboxylase inhibiting herbicides (ACCase) are used for the selective weed control of grasses in broadleaf crops, the objective of this study was to evaluate the safety of the ACCase herbicides when used in industrial hemp. ACCase formulations selected for this study were applied at doses of 0.5, 1, 2, and 4x label rate and included active ingredients clethodim, pinoxaden, sethoxydim, quizalofop, fluazifop, fenoxaprop, and fluazifop+fenoxaprop. The application was performed when plants were 25cm in height using a single nozzle spray chamber calibrated to deliver 140 L ha^{-1}. This study was conducted in a randomized complete block design with seven replications. The response variables were visual symptoms and biomass reduction 21 days after the application for two industrial hemp varieties grown under greenhouse conditions. The general trend observed for most treatments was that as dose increased, plant biomass decreased with prominent visual symptoms on hemp plants. The greatest biomass reduction was observed in treatments that contained clethodim and pinoxaden, with plants having 50% biomass reduction at 445 or 393 and 107 or 47 g ai ha^{-1} for cannabinoid or grain/fiber hemp variety, respectively. Those findings apply to overall industrial hemp biomass production. Active ingredients quizalofop and fenoxaprop may be considered as two possible candidate herbicides for use in hemp. However, since ACCase inhibiting herbicides are directly interfering with a pathway for fatty-acid synthesis, it is necessary through future studies to determine how those herbicides may impact overall plant and/or seed makeup (lignin, oil, and cannabinoid content).

Volunteer Hemp Control with Herbicides. Kirk A. Howatt*, Joseph Mettler, Stephanie DeSimini; North Dakota State University, Fargo, ND (124)

Control of hemp volunteers in the crop that follows hemp seed production is necessary because of indeterminate flowering. Hemp seed matures across a few to several weeks, and ripe seed begins to shatter before the majority of seed is ready for harvest. Field experiments were established near Fargo, ND, to evaluate hemp control with herbicides used in small grains or row crops in separate experiments. Hemp was established under typical production practices without alternative crop competition. Herbicides were applied in 8.5 gpa spray volume to hemp with four leaf pairs. For small grain herbicides, fluroxypyr provided the best control among Group 4 herbicides. In combination with halauxifen, these two gave 92% control. Group 4 and Group 2 herbicides typically resulted in lasting hemp response with new growth demonstrating symptoms for several weeks. Most Group 2 herbicides provided 85 to 95% control. Imidazolinone representatives were not included in these experiments because previous work had shown tolerance. For herbicides used in row crops, Group 14 herbicides gave less than 50% control and plants produced healthy new growth within a week of application. In Group 6, pyridate only gave 25% control but bentazon provided 91% control. Dicamba at 4 oz ae/A gave 72% control but 2,4-D at 12 oz ae/A gave 97% control. Topramezone gave 95% control in this experiment but response has varied relative to environment and plant size. Glufosinate provided 97% control of hemp. Glyphosate also is an excellent option but was left out of this experiment because of exceptional susceptibility to extremely low dose.

Winter Management of Grass Weeds in Grasses Grown for Seed. Kyle Roerig*; Pratum Co-op, Salem, OR (125)

Tall fescue (*Schedonorus arundinaceus* Scherb.) is a cool-season perennial grass grown for seed in western Oregon. In grass seed production, seed purity is extremely important. Contamination of seed lots by seeds from weedy grasses reduces the value of seed lots and increases costs to growers, who pay for extra cleaning steps and lose good seed in the cleaning process. Weedy grasses also compete in the traditional sense by reducing available resources to the grasses grown as a crop. The primary grass weeds are rough-stalk bluegrass (*Poa trivialis* L.), annual bluegrass (*Poa annua* L.), and Italian ryegrass (*Lolium multiflorum* Lam.). Although, annual bluegrass and Italian ryegrass occasionally exhibit the traits of a short-lived perennial, they are annual grasses. The annual growth habit of these weedy grasses and the perennial nature tall fescue is the primary difference exploited in attempting to achieve selectivity with herbicides. With the perennial species rough-stalk bluegrass, control efforts don't vary much from control efforts targeted at annual grasses. Three applications of pre-emergent herbicides are routinely applied to established perennial grasses grown for seed starting in the fall and going through late winter. Glufosinate, metribuzin, or oxyfluorfen are also applied with the objective of using a rate that is lethal to small, emerging grasses but not to large established crop grasses. Glufosinate is applied with caution and reluctance due to crop injury concerns which can reduce seed yield and stand longevity. During the 2021 growing season pre-emergent herbicide trials were placed in established commercially grown tall fescue fields infested with grass weeds during the winter after the first or second applications had already been made by the growers. In these trials, control of weedy grasses was generally poor and ranged from 0-60%. Only when glufosinate was included with the pre-emergent herbicide was control of weedy grasses adequate, ranging from 60-85%. These results underscore the futility of trying to control emerged weeds with pre-emergent herbicides and suggest that grass seed growers need to carefully weigh the potential impact of glufosinate on crop yield and stand longevity against the potential for cleaner, higher value seed.

Chaff Lining Harvest Weed Seed Control in Colorado Dryland Crops. Eric P. Westra*, Todd A. Gaines; Colorado State University, Fort Collins, CO (126)

Field trials evaluating chaff lining efficacy in dryland winter wheat, corn, and grain sorghum were established at two field locations in Colorado in the Fall of 2020 following crop harvest. The main objectives were to evaluate the potential fits and efficacy of chaff lining on reducing weed emergence and seed viability in the field. Different amounts of chaff (no, low, and high) based off yield potentials were established over known quantities of weed seeds, and plant densities were recorded throughout the year to evaluate weed emergence. Weed seed packets were also buried under chaff lines and retrieved at the end of study in 2021 to evaluate weed seed viability under different chaff levels. The corn and sorghum chaff lines were immediately lost due to strong winds, suggesting that chaff lining may not be a practical fit in these systems based on chaff composition. It is possible that modifications such as chopping corn and sorghum chaff at harvest to reduce surface area to weight ratios and improve chaff retention in the field could increase the potential for chaff lining use in these systems, but additional research is needed. Wheat chaff lines were maintained throughout the season and plant densities for downy brome (*Bromus tectorum*), jointed goatgrass (*Aegilops cylindrica*), and feral rye (*Secale cereale)* were correlated to chaff level, with the lowest plant densities in high chaff levels, highest plant densities in the no-chaff treatments, and low chaff treatments having median average plant densities. Preliminary data suggests that chaff lining in Colorado winter wheat has the potential to contribute to reducing weed seed emergence in the field, and currently ongoing evaluations of weed seed packet viability will provide insight into chaff lining impacts on reducing seed viability. Combining and analyzing data from trials replicated in Kansas and Oklahoma will allow for larger scale evaluations of chaff lining efficacy in these three dryland crops across the Great Plains.

Utilizing Preemergence Herbicides to Maximize the Value of Machine-Vision Application Technology. Jason W. Adams*[1], Pete Berry[2], R Joseph Wuerffel[3], Dane L. Bowers[4]; [1]Syngenta Crop Protection, Vero Beach, FL, [2]Syngenta Crop Protection, Monticello, IL, [3]Syngenta Crop Protection, Gerald, MO, [4]Syngenta Crop Protection, Greensboro, NC (127)

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

Introducing UltraLock™, a Novel Deposition and Drift Reducing Adjuvant. Gregory K. Dahl*[1], Ryan J. Edwards[2], Wolf Ryan[3], Joshua Mayfield[4], Joshua J. Skelton[5], Steven A. Fredericks[2], Eric P. Spandl[6], Kevin Krueger[6]; [1]Winfield United, Eagan, MN, [2]WinField United, River Falls, WI, [3]Winfield United, Sheldon, IA, [4]Winfield United, Four Oaks, NC, [5]WinField United, Saint Paul, MN, [6]Winfield United, Arden Hills, MN (128)

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

Female *versus* Male Palmer Amaranth: Are There Opportunities to Explore Gender's Biology as a Management Approach? Ednaldo A. Borgato*, Eduardo C. Rudell, Mithila Jugulam, Anita Dille; Kansas State University, Manhattan, KS (129)

Palmer amaranth (*Amaranthus palmeri*) is a summer annual, C4, with fast growth rate, highly prolific, and dioecious weed. Differences in female and male life cycle were investigated trying to explore gender as an opportunity for improving control of this species. We performed two studies to compare patterns of emergence, growth, and reproduction in female and male plants. Data suggested that different populations required different amount of growing degree days (GDD) for emergence, with female requiring a smaller GDD than males but not for all populations. Also, populations differed in biomass accumulation, but female and male plants were not different. In terms of reproductive aspects, inflorescence in males emerged ahead of females (protandry), but females had the pistils exposed before the anthesis of male plants (protogyny). Summarizing, populations may need different GDD for germination and emergence, and female and male plants may not necessarily display different patterns of emergence. Additionally, different populations may be more competitive than others, given their ability to grow more, but females and males may not be competing against each other, given their similar biomass accumulation. Furthermore, Palmer amaranth has characteristic that maximizes fertility, as female inflorescences emerge already receptive. Life-history can shape growth habits of populations, making it difficult to explore gender for controlling this species. Management decisions could incorporate knowledge of reproductive differences of female *versus* male to reduce seed production. Future research will investigate phenology of female and male Palmer amaranth for better accuracy of GDD requirements for each stage of their life cycles.

WSWS PROJECT 4: TEACHING AND TECHNOLOGY

Nonchemical Strategies for Weed Control in No-Till Dryland Cropping Systems in High Plains. Vipan Kumar*, Rui Liu, Sachin Dhanda, Taylor Lambert; Kansas State University, Hays, KS (137)

The widespread occurrence of herbicide-resistant (HR) weeds poses a serious management challenge for producers in no-tillage (NT) semi-arid High Plains region. The repetitive use of herbicides with the same site of action, and lack of diversity in weed control practices (mainly chemical-based) resulted in evolved resistance to herbicides in major cropland weed species, including horseweed, kochia, Palmer amaranth, common waterhemp, and Russian thistle. For instance, glyphosate resistance in kochia and Palmer amaranth has widely spread in the High Plains region. In addition, several biotypes of both weed species have also evolved with multiple resistance to 4- to 5 different herbicide sites of action (SOA). Managing HR weeds is complex and varies both within and between regions. Nonetheless, increasing herbicide costs to manage these HR weeds in combination with low commodity prices necessitates the development of ecological-based, alternative weed control strategies in the region. Several nonchemical strategies, including cover crops, occasional/strategic tillage, alteration in agronomic practices, and harvest weed seed control (weed seed destruction and chaff lining) have shown promising results in managing HR weeds in recent years. This paper aims to highlight the role of these nonchemical strategies for HR weed control in the High Plains region, with emphasis on ecological, economic, and agronomic benefits. We will also illustrate current research gaps and propose new research and outreach needs for their adoption in the region.

Music and Weed Control Research: Can You Carry the Tune? Pamela J.s. Hutchinson*; University of Idaho, Aberdeen, ID (138)

Listening to music has been used for speech therapy. In recent studies, a relationship has been shown between being a musician and having enhanced math and statistical skills. For instance, children with some musical training had better discrimination of frequency and rhythm than children with no training, and those skills translate to having an enhanced ability to detect patterns in visual tasks. Hmmm, patterns - visual tasks? What has that got to do with weed control research, you say? The assessment of good versus bad control is important when conducting visual weed control ratings. In addition, seeing the distribution and density of weed species in a test plot is also critical e.g., does the herbicide treatment control all weed species present or are some left while others are gone? Is the control in one plot the same as control by that treatment in other replications within the trial? As a percussionist - player of drums - I believe that I see the patterns in visual ratings transposed to a higher level of assessment in weed control research trials than if I could not even contribute additional cowbell. Can you carry the weed control tune?

Reaching and Interacting with Audiences on Virtual Formats. Jeanne S. Falk Jones*; Kansas State University, Colby, KS (139)

With restrictions on connecting with our clientele in person, there has been an added emphasis on connecting with farmers and agronomy professionals electronically. This can be a variety of ways, including virtual meetings and social media. The virtual Crop Talk webinar series was the replacement for numerous local meetings on area-specific topics (i.e. Palmer amaranth control). The Crop Talk webinar series was held over a 6-week period in both 2021 with 9 webinars to address questions and topics from farmers. Over 425 farmers and agronomy professionals from eleven states and six counties registered for the series in 2021. Over 400 attended live webinars in 2021 and nearly 800 watched recordings of the webinars. Nearly 140 continuing education credits for certified crop advisors were also earned by the attendees. One specific effort by the organizers and presenters was an increased amount of facilitated interaction with the audience. This was done by utilizing poll questions throughout the presentations via Zoom webinar or Poll Everywhere. In addition, attendees could send in questions using the chat box, Q&A box, email or text message. In surveying the attendees of these virtual meetings, a majority rated the virtual meetings as 'OK'. Many like the opportunity to attend meetings that they would not normally attend. Others would like to return to in-person meetings. The attendees noted that they liked the interaction with speakers. When listing disadvantages, many noted poor/slow internet service and lack of interaction with other farmers.

WSWS PROJECT 5: BASIC BIOLOGY AND ECOLOGY

Exploring Genetic Variation Underlying Adaptive Traits in Invasive *Bromus tectorum*. Samuel R. Revolinski*[1], Peter J. Maughan[2], Craig Coleman[2], Ian C. Burke[1]; [1]Washington State University, Pullman, WA, [2]BYU, Provo, UT (103)

Bromus tectorum L. is an invasive weed infesting large areas of the intermountain west. Adaptive traits such as flowering time and height are heritable in B. tectorum. However, the underlying genes and genetic architecture controlling these traits remain unknown. There were 121 genotypes (full-sib families) grown in the greenhouse, vernalized, and allowed to flower so flowering time traits and height could be assessed. We identified 21 significant single nucleotide polymorphisms (SNPs) associated with height (cm), days to first visible panicle, days to first joint, days to first ripe seed and days to 50% ripe seed. Homologs of HEADING DATE REPRESOR 1 (HDR1), FAR-RED ELONGATED HYPOCOTYL3 (FHY3), FAR1-RELATED SEQUENCE 6 (FRS6), FAR1-RELATED SEQUENCE 5 (FRS5), Dehydration-responsive element-binding protein 1F (DREB1F), Cullin-3A (CUL3A), Gibberellin 20 oxidase 2 (GA20OX2), and PHYTOCHROME-DEPENDENT LATE-FLOWERING (PHL) were identified as candidate genes. A reference genome was assembled for B. tectorum using PacBio long-read sequencing and was improved with all-paths contig creation and Omni-C scaffolding. The assembly was 2,482.01 Mbp long and has an N50 of 357.431 Mbp with BUSCO results indicating that 92.2% of the conserved othologous genes for viridiplantae are complete with in the assembled genome, with only 2.8% being duplicated, as expected for a diploid. The candidate genes identified using GWAS can be used to offer insights into the mechanisms controlling adaptive traits in B. tectorum. Our results demonstrate large effect loci are present for adaptive traits in B. tectorum indicating the species is pre-adapted to adapting to new environments.

Comparative Genomics of the Tumbleweeds Russian Thistle and Kochia in the Western US. Philip Westra*[1], Todd A. Gaines[1], Jacob S. Montgomery[1], Eric L. Patterson[2]; [1]Colorado State University, Fort Collins, CO, [2]Michigan State University, East Lansing, MI (104)

Kochia and Russian thistle are two unusual tumbleweeds that are commonly found in Colorado and much of the western United States and Canada where both weeds inhabit crop and non-crop land. Both species form a special abscission layer near the soil surface which allows the plants to snap off in strong winds. When blowing across the landscape in strong winds, both drop seeds in meandering wind driven trails ensuring that their genes spread quickly in diverse ecosystems. As part of the International Weed Genomics Consortium, we are developing the full genome sequence of Russian thistle using multiple sequencing platforms to develop deep, basic, and high-quality sequence that will facilitate delving into the basics of herbicide resistance and abiotic stress tolerance. At 1.3 Gb, the Russian thistle genome is slightly larger that the 1.0 Gb genome of kochia. The kochia genome project is further along than the Russian thistle genome. Dr. Eric Patterson of MSU assembled the kochia genome for his PhD project, and he and his team at MSU have now annotated the genome. We will carry out similar steps with Russian thistle and the comparisons of these two closely related species will open exciting new insights to how that have become the successful weeds they are. The Russian thistle genome sequence is nearing completion on multiple sequencing platforms which will help in addressing the multiple ploidy levels found in the Salsola complex in the western US and southern Canada. We hope to gain insights into the molecular basis for abscission layers formed by both species. Both of these genome sequencing projects are benefiting from the excellent platforms being used for major global weeds in the new International Weed Genomics Consortium project managed by Dr. Todd Gaines at Colorado State University.

Inheritance of 2,4-D Resistance in *Conyza sumatrensis* Population from Brazil. André Lucas Simões Araujo*[1], Jéssica Ferreira Lourenço Leal[2], Amanda dos Santos Souza[3], Sarah Morran[1], Todd A. Gaines[1], Camila Ferreira de Pinho[4]; [1]Colorado State University, Fort Collins, CO, [2]UPL, São Paulo, Brazil, [3]BASF, São Paulo, Brazil, [4]Universidade Federal Rural do Rio de Janeiro, Seropédica, Brazil (105)

A population of *Conyza sumatrensis* has evolved resistance to 2,4-D, saflufenacil, glyphosate, diuron, paraquat and diquat. In Brazil, the use of 2,4-D is a primary strategy to control *Conyza* spp. This study aimed to determine the inheritance of resistance of a population of *Conyza sumatrensis* to 2,4-D. Susceptible (S) individuals and resistant (R) individuals were selected for bi-parental crosses. The phenotype of R exhibits a rapid physiological response when treated with 2,4-D. The F1 generation was derived from the R and S bi-parental crosses, containing two S? x R? and three reciprocal R? x S? crosses. The F1 plants were treated with 2,4-D (1005 g ae ha^{-1}) once they reached the growth stage of 10-12 cm. Every F1 plant survived after the application, except the S parental, as expected. Twenty-seven individuals of F2 derived from the cross R? x S? were self-pollinated to generate F3. In the 27 lines generated of F3 plants, 16 plants of each line were treated with 2,4-D at the rates of 502.5 and 1005 g ae ha^{-1}. A visual assessment was performed 21 days after treatment (DAT) and plants were compared with parentals 24 hr after application. The F3 segregation after 2,4-D application was 9:4:14 in which 9 lines exhibited the rapid response, 4 did not survive and 14 contained both surviving and controlled individuals. These results suggest some possible genetic inheritance models, however further molecular biology studies will be performed to identify the genes involved with this rapid physiological response.

Identification and Validation of Cytochrome P450 Involved in Tembotrione Metabolism in HPPD-resistant Palmer Amaranth (*Amaranthus palmeri*). Carlos A. G. Rigon*[1], Crystal D. Sparks[1], Lennart Charton[2], Anita Küpper[3], Roland S. Beffa[4], Franck E. Dayan[1], Todd A. Gaines[1]; [1]Colorado State University, Fort Collins, CO, [2]Bayer AG, Frankfurt Am Main, Germany, [3]Bayer AG, Frankfurt, Germany, [4]Senior Scientist Consultant, Frankfurt, Germany (106)

Cytochrome P450 monooxygenases (P450s) are heme-dependent proteins that can oxidize endogenous and exogenous molecules in phase I of metabolism. A tembotrione-resistant population of Palmer amaranth from Nebraska (NER) was characterized to have a faster hydroxylation than a susceptible population (NES). This reaction is usually catalyzed by P450. The objectives of the study were: Identify candidates P450 by RNA-seq analysis and validate candidates P450s using yeast as a heterologous system to provide evidence of tembotrione-hydroxylation. An RNA-seq experiment was performed using Pseudo-F2 tembotrione-resistant and -susceptible plants originated from two separate NER x NES crosses. DESeq2 was used to identify differential gene expression. Yeast strains harboring the genes for plant *P450-reductase* 1 or 2, respectively, were transformed with candidate *CYPs* using the expression plasmid pYES2. A known P450 gene from corn (*Nsf1*) that metabolizes tembotrione was used as a positive control. Three *CYP72A219*-like and one *CYP81E8*-like were identified to have higher constitutively transcription in NER. Hydroxy-tembotrione was detected in the supernatant from yeast transformed with *Nsf1* and from one version of *CYP72A219*-like, showing a peak at least three-fold higher than the background signal in the empty control. Any metabolites were detected in this expression system using the other two *CYP72A219*-like and *CYP81E*-like; however, the involvement of these genes in tembotrione metabolism *in planta* may not be dismissed. At least one *CYP72A219*-like gene is involved in the metabolism of tembotrione in Palmer amaranth. The resistance trait may be multigenic and other P450s may be involved.

Does the Presence of Weeds Increase Crop Injury Potential from Herbicides? Andrew R. Kniss*[1], Albert T. Adjesiwor[2]; [1]University of Wyoming, Laramie, WY, [2]University of Idaho, Kimberly, ID (107)

Presence of weeds at the time of crop emergence is discouraged because early season weeds are known to compete with the crop. Previous research has shown that the mere presence of weeds at the time of crop emergence can impact yield potential by triggering shade avoidance responses in the crop. The emerging crop plants can sense the light reflected from weeds and alter growth to grow taller, often at the expense of root production and branching. As herbicide-resistant weeds continue to increase, non-herbicidal weed management methods like cover crops are being encouraged. Cover crops, if growing at the time of crop emergence, may induce shade avoidance responses in the crop similar to weeds. Shade avoidance syndrome includes a long list of physiological responses that have been well-described in some plant species. In some cases, shade avoidance can result in reduced chlorophyll concentration in leaf tissue, and increased presence of reactive oxygen species which are detrimental to the plant. Because photosynthetic systems are affected by shade avoidance signals, it is possible that efficacy of certain herbicides may be impacted by the presence of either dense weeds or a cover crop. Greenhouse and field research suggests that sugarbeet (*Beta vulgaris*) grown near weedy environments is more susceptible to injury from herbicides that inhibit photosystem II and protoporphyrinogen oxidase.

Shade Avoidance Alters the Root Architecture of Sugar Beets. Joe G. Ballenger*, Andrew R. Kniss; University of Wyoming, Laramie, WY (108)

In previous research, we have determined that shade avoidance contributes significantly to sugar beet yield loss due to weeds. The developmental stage at which the plant is exposed to neighbor-sensing signals is known to be an important determining factor of yield loss, but little is known about how crop growth stage at the time of exposure to shade avoidance signals effects external sugar beet root morphology or internal root anatomy. Sugar beets were grown surrounded by soil or near grass and then transferred from grass to soil or soil to grass between 15 and 20 days after planting. Exposure to neighbor-sensing signals for the first 15 to 20 days after planting increased the formation of fibrous roots in sugar beet. Cryosectioning was performed on sugar beets, and xylem tissues were observed through autofluorescence microscopy. An early lag in xylem formation in sugar beets grown near grass dissipated by 30 days after planting. Light reflected from other plants temporarily affects the xylem tissue formation early in development, and causes permanent changes in the external anatomy later in development.

Potential of Biofumigants Products to Reduce Germination and Establishment of Native and Non-native Grasses. Lilly L. Sencenbaugh, Jane Mangold, Danielle Ulrich, Lisa J. Rew*; Montana State University, Bozeman, MT (109)

Non-native annual grasses are invading western rangelands and novel approaches are needed to supplement existing weed management strategies. The aim of this study was to investigate biofumigants as a potential control strategy for two non-native annual grasses (downy brome, *Bromus tectorum* and ventenata, *Ventenata dubia*), and their effects on native perennial grass species (bluebunch wheatgrass, *Pseudoroegneria spicata* and Idaho fescue, *Festuca idahoensis*). We tested the effect of the mustard biofumigant, *Brassica juncea*, to suppress germination and establishment of the four grass species in two controlled environment studies. In the first study, germination, and radicle and hypocotyl length of the four species was assessed when the biofumigant was applied as leachate, made either from seed meal or plant mulch. In the second study, we evaluated the effect of four treatments; seed meal leachate, mulch leachate, and ground seed meal and whole plant mulch applied to the four species sown in soil. In the first study, both leachates reduced percent germination, radicle and hypocotyl length for all species at medium to high rates, with bluebunch wheatgrass being the most tolerant. Similar patterns were observed for seedling establishment in soil when using seed meal leachate, seed meal, and mulch, but mulch leachate had no effect. Seed meal alone reduced above-ground biomass of seedings for all species but most for the two non-natives, whereas as the seed meal leachate and plant mulch decreased biomass of the two non-natives and Idaho fescue but not bluebunch wheatgrass. Overall, bluebunch wheatgrass was the most tolerant and Idaho fescue and the non-natives were similarly sensitive. Further research in controlled and rangeland environments is required to confirm our preliminary results demonstrating the potential of mustard biofumigation to control non-native annual grasses.

Transgenerational Effect of Weed Competition on Wheat. Albert O. Kwarteng*[1], Albert T. Adjesiwor[2]; [1]University of Idaho, Moscow, ID, [2]University of Idaho, Kimberly, ID (110)

Plants are subjected to several forms of biotic and abiotic stress and have thus, evolved several mechanisms to cope with these stress conditions. Studies have shown that plants can store and recollect memory of a previous stress exposure and respond to it accordingly. This memory could either be advantageous or maladaptive to the plant in subsequent generations. This research is, therefore, aimed at understanding how multigenerational weed exposure affects phenotypic, gene expression, and DNA methylation plasticity in spring wheat (*Triticum aestivum*). Spring wheat was planted in the center of plastic pots surrounded by either kochia (*Bassia scoparia*), Italian ryegrass (*Lolium multiflorum*), wheat, or no surrounding plants. The treatments were arranged in a completely randomized design with 15 replications. Seeds harvested from the first generation were used to plant the second generation, and the process is being repeated under the same conditions to obtain the third, fourth, and fifth generations. Relative to wheat with no surrounding plants, wheat-kochia, wheat-ryegrass, and wheat-wheat treatments reduced seed yield by 7, 26, and 43%, respectively, in the first generation. In the second generation, wheat-kochia, wheat-ryegrass, and wheat-wheat treatments reduced seed yield by 90, 93, and 89%, respectively, compared to wheat with no surrounding plants. These preliminary results suggest a potential maladaptive impact of transgenerational memory of weed stress on wheat. The third, fourth, and fifth generations, together with the biochemical, transcriptomic, and epigenetic data from the common garden experiments would give us a better understanding of the mechanisms involved in this observation.

EDUCATION & REGULATORY SECTION

What Was WSWS Like in the Past 25 Years? Contemplating How to Build the Future on This Foundation. Vanelle F. Peterson*[1], Philip A. Banks[2], Rodney G. Lym[3], Don W. Morishita[4]; [1]retired Dow AgroSciences, Fort Collins, CO, [2]Marathon-Agricultural & Environmental Consulting, Inc., Las Cruces, NM, [3]North Dakota State University, Fargo, ND, [4]University of Idaho, Kimberly, ID (132)

How can the past changes to the Western Society of Weed Science (WSWS) enlighten us to what changes may be necessary in the future of WSWS and Weed Science? The overall objectives of the Western Society of Weed Science (WSWS) have not really changed over the years since the beginning in 1938. Emphasis continues to be on education and research on weeds and on legislation that effects weed science. What has changed are the research priorities, techniques and methods used, and the representation of members within the society. Molecular biology and ecology have emerged as research priorities. What sorts of hypotheses will be tested in these areas of research and how will it aid agriculture in the west? Electronic devices are used for data collection, reporting, achieving, and just about everything we do. How will we ensure that these research results are archived in such a way that they do not get lost in cyberspace? Membership from academia and industry used to be about equal before the consolidation of chemical companies (43% and 47%, respectively in 1993). Now membership is about 55% academia/public and 30% industry/private. Membership from agencies (federal, state, and counties) has doubled. Our membership is more diverse than in the past. How should these changes in membership affect our meetings?

A History of the Weeds of the West Publication and What it Has Meant to WSWS. Philip A. Banks*[1], Tom Whitson[2]; [1]Marathon-Agricultural & Environmental Consulting, Inc., Las Cruces, NM, [2]Retired, Santa Fe, NM (133)

The Weeds of the West publication was the brainchild of Tom Whitson (Univ. of Wyoming) who served as the Editor of the book. The first edition was published in 1991 with the last printing (11th) in 2013. All remaining books in inventory were sold by the end of 2017. The publication was a joint effort between the University of Wyoming and the Western Society of Weed Science. The book contains high quality photos (usually three) of 350 weed species with a taxonomic description and where the weed is most commonly found. There were numerous WSWS members and students who contributed to the publication either through the donation of photographs or from editing of the revisions as nomenclature changed over time. This endeavor was truly a team effort from all WSWS members. Books were available for purchase through the WSWS Business Office, from the University of Wyoming publications office, through various University Extension publications offices, in commercial bookstores, and in various State and National Park bookstores. A copy of the book in electronic format is currently available for no charge from the University of Wyoming publications office (http://www.wyoextension.org/publications/Search_Details.php?pubid=696&pub=WSWS-l) Over the lifetime of the book, 190,000 copies were printed and sold. Total gross sales were approximately 2.25 million dollars with a net profit to WSWS of over $290,000. Additional profits were received by the University of Wyoming, as well, to support scholarships for Weed Science students. Besides the income from the book that allowed WSWS to be financially comfortable, it increased the visibility and professional reputation of the Society. This was best exhibited when WSWS named news broadcaster Tom Brokaw an Honorary Member in 2009. In giving an address to the Western Governors Conference he mentioned that Weeds of the West was his favorite book and he used it often to identify weeds on his ranch in Montana.

Weed Science Graduate Student Education: Past and Present. Carol Mallory-Smith*; Oregon State University, Corvallis, OR (134)

Weed science is often described as a diverse discipline that includes weed control/management, herbicide science, weed biology, ecology, etc. This broad description is a reflection that Weed Science has struggled to define itself as a discipline. Because of this struggle, there have not been consistent core curricula for weed science graduate students. Nor is there an accepted body of knowledge that all graduates are required to possess. Most weed science programs are tailored specifically for the individual student and the research being conducted. Often weed science research is chasing the newest technology areas for example, Global Imaging Systems or "omics". Most current weed scientists are not experts in these technologies, so the course work will be provided by faculty outside of agriculture. The challenge is blending the new areas with weed science questions. In addition, new curricula will have to be added to graduate education. Time constraints for graduate students to complete their degree requires that choices will have to be made as to what course work will dropped. The questions become which classes will removed and are there classes that all weed scientists agree must be taken for a student to qualify as a weed scientist. Further, class room education must be balanced with research training and experience.

Industry and the WSWS: A Tale of Cooperation, Communication and Consternation. Charlie Hicks*; Bayer CropScience, Ft. Collins, CO (135)

Private industry has had a long and varied history with the Western Society of Weed Science. Industry involvement has been critical to the success of the WSWS. Many company representatives have served in positions such as president, board members, committee chairs, program sponsors, authors and paper judges. In recent years, industry consolidation has resulted in fewer companies and individuals being involved with the society. Moving forward, it will be critical to the success of the society to maintain industry membership and involvement. Discussions on how to ensure future involvement need to take place.

Weed Science and Washington: Interactions and Opportunities. Jill Schroeder*[1], Lee Van Wychen[2]; [1]New Mexico State University, Las Cruces, NM, [2]Weed Science Society of America, Alexandria, VA (136)

Over the last 25 years, weed science through the national and regional professional societies has engaged with Washington agencies and legislators to promote the research, education, and awareness of weeds in managed and natural ecosystems. In February 1999, the weed science societies hired Rob Hedberg as their first full time Director of Science Policy (DSP). Lee Van Wychen has been in the position since August 2005. Some of the core duties of the DSP position includes: 1) making the expertise of the national and regional weed science societies known and readily available to Congress, Federal Agencies, and other stakeholders; 2) coordinating comments on specific science, regulatory, and policy issues that are of concern to the societies or where the societies have specific competencies; and 3) promoting initiatives such as National Invasive Species Awareness Week (NISAW) that help advance and fund weed and invasive plant science research, education and extension. The DSP position has grown in scope over the years to include activities like managing the Weed Science Policy Fellows Program and conducting the annual survey for the most common and troublesome weeds. In addition, the DSP helps nominate weed scientists to Federal advisory boards and coordinates the selection process for the WSSA-EPA Liaison, WSSA-NIFA Fellow, and the weed science representative for the USDA-APHIS Technical Advisory Group for the Biological Control Agents of Weeds. The EPA liaison position was established in 2007 and the NIFA fellow positions in 2012. Steve Dewey (USU) was the first EPA liaison, followed by Jill Schroeder (NMSU), Mike Barrett (UK), Greg Kruger (UNL), and currently Mark VanGessel (UD). Don Shilling (UGA) was the first NIFA fellow and we are currently represented by Jim Kells (MSU). The individuals in these positions are volunteers who interact with the respective agencies to educate and provide requested input on weed science issues related to pesticide regulation and need for federal grant support. Each liaison and fellow have brought different expertise to their agencies but all have reached out to colleagues in the field to help address questions before the respective agency. In addition, they serve on the WSSA Science Policy Committee and maintain a close working relationship with the DSP. Weed science visibility in federal government agencies has increased as a result of these outreach activities and our professional society members are increasingly contacted for information as they deal with pest related issues. Key weed management issues going forward include the impact of Endangered Species Act (ESA) compliance, pesticide label changes in light of increasing herbicide resistance, funding for weed and invasive plant research, prevention and management, and the impact of invasive weeds on fire cycles and western ecosystems, and more. In light of our increased visibility in Washington, weed scientists must actively engage to provide much needed research and expertise to help inform policy and regulation going forward.

SYMPOSIUM: New Technology for Physical Weed Control

Deep Learning and Robotics Are Enabling the Next Era of Weed Management. William Patzold*; Blue River Technology, Sunnyvale, CA (061)

Blue River Technology is bringing the next generation of smart machines to address current challenges being faced in agriculture. With the use of artificial intelligence and machine learning, sprayers are being taught to recognize crops and weeds in real-time, thus allowing the application of herbicides to weeds with a high degree of accuracy and precision. The development of these intelligent sprayers requires significant investment in sensors (e.g., cameras), human labeled datasets, convolutional neural networks powered by graphical processing units (GPUs), and hardware (e.g. nozzles) able to act on this information in real time. While Blue River Technology is using chemical weed control strategies to management weeds, these intelligent weeding platforms can also be used to mechanically management weeds in a variety of agronomic and vegetable crops. Blue River Technology has been continuously testing in agronomic crops since 2017 with commercial sprayers available in the near future.

The Business of Robotic Weed Control. Ryan Herbon*; AgMechtronix, Silver City, NM (062)

The past 10 years have seen tremendous advancements in robotic agriculture technologies. During that period, the automated thinning of lettuce crops has gone from near zero to near 100%, freeing up those workers that previously hand thinned lettuce to be available for more difficult to automate tasks. As a single task is automated, the next "low hanging fruit" becomes the focus for automation. Currently there are many companies around the world pursuing the robotic removal of weeds. Agmechtronix is no exception to this trend. Being driven by easily accessible open-source Artificial Intelligence Machine Learning algorithms and hardware for machine vision, the weed detection possibilities for robotic equipment has moved exponentially past what was possible only 5 years ago. Now terabytes of images can be collected in the field, labeled in the lab, and be used to "teach" the robots what is a weed, what is a crop and even what type of weed it's looking at. Different weed removal strategies can be implemented for different weed varieties, maturity, proximity to crop and soil conditions. As more acres are covered with these machines, more data will be collected, and the models will continue to improve. The weed removal step once a weed is identified is the other big part of the equation. Some weeds can be sprayed while some can be removed with mechanical knives. Each crop has differing needs for weed control and a broad stroke, modular approach to the removal is needed. Agmechtronix is focusing on this modular approach to a hybrid spray and knife systems for the removal of weeds from many types of crops.

Laserweeding. John Mey*; Carbon Robotics, Seattle, WA (063)

By deploying robots created by Carbon Robotics, farmers will experience the following benefits: 1. A significant increase in crop yield and quality: Lasers leave the soil microbiology undisturbed, unlike tillage. The lack of herbicides and soil disruption paves the way for a regenerative approach, which leads to healthy crops and higher yields. 2. A reduction in overall costs: Automated robots enable farmers to reduce the highly variable cost of manual labor as well as reduce the use of crop inputs such as herbicides and fertilizers. Labor is often farmers' biggest cost and crop inputs account for 28.2% of their total expenses. Reducing costs in both these areas is a huge benefit. 3. Adoption of regenerative farming practices: Traditional chemicals used by farmers, such as herbicides, deteriorate soil health and are tied to health problems in humans and other mammals. A laser-powered, autonomous weed management solution reduces or eliminates farmers' needs for herbicides. 4. An economical path to organic farming: One of the largest obstacles to organic farming is cost-effective weed control. A solution to weed management that doesn't require herbicides or an increase in manual labor provides farmers with a more realistic path to classifying their crops as organic. 2022 Implement LaserWeeder: As a liftable agricultural implement, the 2022 LaserWeeder offers unique benefits over the autonomous version, including: i) Higher Performance. With 30 lasers spanning three crop rows (roughly 20 feet wide), this model has an average effective weeding capacity of two acres per hour. ii) Flexible Configuration. The robot is fully adjustable for crop row widths ranging from 60 to 84 inches. Adjustments for transitioning between different crops can be made via a touch-screen without leaving the comfort of the cab. iii) Tractor Ready. The LaserWeeder is towed by common row tractors with a three-point hitch. About Carbon Robotics: Carbon Robotics builds innovative agricultural tools that empower farmers to operate more efficiently. It launched its first product, the Autonomous LaserWeeder, in April 2021 and revealed its newest LaserWeeder in February 2022. To scale manufacturing of its implement, the company raised a $27 million Series B in 2021. Carbon Robotics was founded in 2018 and is based in Seattle. For more information, visit: https://carbonrobotics.com/.

Physical Methods to Reduce Hand Weeding in Vegetable Crops. Steve Fennimore*; University of California - Davis, Salinas, CA (064)

Vegetable crops are nearly all grown for food, many of which such as carrot and lettuce, are selected by the consumer based on appearance. The standards for fresh vegetable appearance are very high, and weeds must be controlled to prevent weed competition from damaging produce quality. There are some vegetable herbicides, but most provide only partial weed control which must be supplemented by additional inputs such as cultivation and hand weeding. Handweeding is very effective but agricultural labor is in short supply and increasingly expensive. Most of the vegetable herbicides are more than 40 years old and new products are rare. One of the more promising new weed control tools for vegetable crops are automated weeders. Tools such as cultivators are increasingly more automated and more effective at removing weeds. Many of the newest machines now can differentiate crops from weeds. Machines like the Stout cultivator and Farmwise Titan robot use mechanical cultivation to uproot weeds, and their actuation is very much like a human hoe hand. With the automated weeders hand weeding is still needed to remove weed escapes, but the time of hand weeding is greatly reduced. The Stout cultivator reduced hand weeding times in lettuce 15 to 62%, and the Farmwise Titan reduced hand weeding times 13 to 55%. The greatest reductions in hand weeding times from the automated weeders occurs when weed pressure is highest. So far there are no organic compliant herbicides that provide preemergence weed control on the market. However, soil disinfestation with steam can be used to kill weed seeds in the soil seedbank in conventional and organic fields. Soil disinfestation with steam greatly reduces weed emergence by killing weed seed in the seedbank. Therefore, the residual effect of steam disinfestation on weeds is due to reductions in seedbank viability. Steam injected into a 4 inch band aligned with the seedline followed a day later by planting in the steam disinfested band has resulted in >90% weed control in carrot and lettuce. Band steaming reduced hand weeding times by 80% in carrot and 91% in lettuce. Similarly crops planted in the steamed bands had improved crop quality due to suppression of soilborne diseases.

Electric Weed Control in Perennial Crops. Marcelo L. Moretti*; Oregon State University, Corvallis, OR (065)

Electric weed control (EWC) is a non-chemical method to kill weed foliage and roots that does not disturb the soil. A high voltage electric current is passed through the target species to vaporize cellular water and rupture the cell wall structure. Weed control with electric current has been studied for decades. Commercial units designed to operate above the crop canopy rely on a height difference between the crop and weed. There is a renewed interest in this technology as it can be used in organic systems and as an herbicide-resistance management tool. Zasso and Rootwave now offer electric weed control equipment for perennial crops, primarily tree crops. Unlike earlier versions, this equipment applies electric current using two sets of electrodes in constant contact with the weed foliage and soil. One example of this type of equipment is the electric weeder EH-30 Thor made by Zasso. This unit has a 24 kW generator and can generate a current between 5 to 12 kV. Energy can be further controlled by the speed of operation. The EH-30 delivers up to 17 kJ m^{-2} at 0.4 km h^{-1}. Plant wilting or necrosis and other effects of current application are immediately noticeable. Performance of electric weed control is dependent primarily on soil texture and moisture, weed species, weed density, and size. Electricity has imposed 80% control on Italian ryegrass at 2 km h^{-1} and reduction in seed production even at 6.8 km h^{-1}. Studies in electric weed control in tree crops are in the early stages, but the results are promising. It is likely that electric weed control will become more prevalent in perennial crops as accessibility to the technology increases.

Electric Weed Control in Row Crops. Lynn M. Sosnoskie*; Cornell University, Geneva, NY (066)

Herbicides are the predominant tools used in many annual cropping systems to manage unwanted vegetation. However, the use of chemical control products is not always effective/desirable due to the evolution of herbicide resistance, limited release of new active ingredients, concerns with crop injury and off-target movement, and changing regulatory environments and public perceptions about pesticide use. Consequently, these is growing interest in the evaluation and adoption of novel technology for weed control. Electrical weeders, like the commercially available, tractor-mounted Weed Zapper™, control weeds that are in-row and above the crop canopy by applying a high voltage electric current directly to unwanted vegetation. The flow of electricity through the plant generates heat, which causes water in cells to vaporize; in turn, the resulting pressure causes tissues to burst and die. Personal communications with weed science colleagues across the United States suggest that there is a resurgence in grower interest in electrical weeding technology among growers. This includes New York, where several organic farms and a custom operator have established collaborations with Cornell and Cornell Cooperative Extension to optimize the technology. Results from studies (2020 and 2021) in soybean (*Glycine max*) and table beets (*Beta vulgaris*) showed significant reductions in weed biomass and reproductive output where growers used the commercially available Weed Zapper™ for vegetation management as compared to check plots (no electrical weeder activity). Under optimal use conditions (i.e. applied to succulent, vigorously growing weeds), aboveground fresh weight and reproductive output of common lambsquarters (*Chenopodium album*), Powell amaranth (*Amaranthus powellii*), common ragweed (*Ambrosia artemisiifolia*), velvetleaf (*Abutilon theophrasti*), and foxtail species (*Setaria spp.*) were reduced by up to 97% 7 to 21 days after treatment (species are listed in order from most sensitive to least sensitive in Cornell trials). Root death was also recorded. Substantial injury was not observed in soybean but did occur in table beets; the damage was presumed to occur under dry soil conditions where the electrical current appeared to preferentially pass through beet roots. The unit setting (high, medium, low) also impacted the degree of injury observed. In 2022, replicated field trials will specifically evaluate how species type, plant size, plant density and spatial arrangement, soil moisture content, and application parameters directly influence weed control success and crop injury potential.

Biodegradable Mulches in Perennial Crops. Lisa W. DeVetter*; Washington State University, Mount Vernon, WA (067)

Specialty fruit and vegetable production systems are increasingly utilizing plastic mulches for weed management. Plastic mulches provide the opportunity to suppress weeds while minimizing the use of herbicides and hand labor. These benefits can be especially useful in organic systems where the availability of effective tools for weed management are limited. Additional benefits of plastic mulches include modified soil and canopy temperatures, reduced soil-water evaporation, and increased yields and quality. However, plastic mulches are largely manufactured using non-degradable polyethylene. Annual use of non-degradable plastic mulches leads to large quantities of waste generation that is rarely recycled and often ends up in landfills, stockpiled on farms, or incinerated. Some mulch waste also ends up as an environmental pollutant. Soil-biodegradable plastic mulches are manufactured with different feedstocks that can biodegrade in soils after tillage. Results from numerous trials have shown biodegradable plastic mulches can provide the same benefits as non-degradable plastic mulches without the waste generation. Barriers to adoption include perceived higher costs, mulch color, use in organic and fumigated systems, and uncertainty about breakdown. Future work should continue comparing horticultural responses of biodegradable plastic mulches relative to standard grower practices, performing cost-benefit analyses, and characterizing mulch breakdown across soil types and climates.

WORKSHOP: Weeds and Wildfires in the West?

Developing the Team to Manage Invasive Plants: Who Should be at the Table? Kassim Al-Khatib*; University of California, Davis, CA (146)

A successful invasive species response process - planning, prevention, detection, identification, mitigation and recovery - requires well-tuned, coordinated cooperation among many organizations and individuals. The role of integrated pest management in this continuum is significant but has not always been well included. IPM researchers, extension specialists and practitioners have important roles from planning through mitigation. And when eradication is not possible, IPM becomes a key to recovery as IPM practices help manage the newly established species with minimal detrimental impacts. The Western IPM Center Invasive Species Signature Project is designed to improve the integration of IPM in the response continuum. The program brings together interested partners in the West - including federal, regional, state, industry, academic, and local entities - to address invasive insects, plants and plant pathogens, and to plan coordinated responses to emerging threats. The project will generalize specific response plans and develop broadly applicable IPM protocols suitable for a wide range of invasive species.

Strategic, Landscape-Scale Management for Invasive Annual Grasses. Brian A. Mealor*; University of Wyoming, Sheridan, WY (147)

A common recommendation for managing invasive plants is to work at landscape scales in a cooperative manner. In practice, this principle is difficult to implement. This presentation will discuss lessons learned from cooperative groups working to manage narrowly-distributed species from an early detection-rapid response framework to well-established, widely-distributed species using multi-criteria spatial prioritization. By more closely aligning science and practice, we are testing feedback systems to enhance decision-making and, hopefully, to improve weed management success over the long term.

Invasive Plants, Changing Wildfire Regimes, and the Quest to Protect Habitats and Homes in Orange County. Jutta Burger*[1], Dave Erickson[2], Danny Fry[3]; [1]California Invasive Plant Council, Berkeley, CA, [2]Orange County Fire Authority, Irvine, CA, [3]Natural Communities Coalition, Irvine, CA (148)

Southern California wildlands have been subjected to more frequent fire in recent years than they have historically experienced. Invasive annual plants have expanded under these conditions and have ensured the almost continuous supply of flashy fuels for future fires. The Central / Coastal NCCP/HCP and surrounding parkland of Orange County represents over 40,000 acres of highly biodiverse – and flammable -- protected habitat that lies immediately adjacent to a large urban human population. We will discuss the invasive plants that factor into this equation, fire management methods, and a regional collaborative for habitat protection that incorporates the interacting local threats of invasive plants, habitat degradation, and wildfire.

Economics and Low Cost Management Options for Medusahead. Jeremy James*[1], Matthew J. Rinella[2], Josh S. Davy[3], Larry C. Forero[4]; [1]UCANR, Browns Valley, CA, [2]USDA-ARS, Miles

City, MT, [3]University of California Cooperative Extension, Red Bluff, CA, [4]University of California Cooperative Extension, Redding, CA (149)

Invasive plant management on rangeland is limited because land managers are often uncertain about the economic benefits of controlling invasive plants and common tools to control invasives are often costly compared to profitability of rangeland livestock production. We used the invasive annual grass medusahead (*Taeniatherum caput-medusahead* L.) as a model system to address these issues. First, tracked changes in yearling steer weights across the growing season (March to May) for two years in 11, 2.1-ha pastures where medusahead abundance was experimentally manipulated and integrated weight gain results with market data to illustrate how medusahead impacts on gross profitability. Second, we applied low rates of aminopyralid treatments (0 or 55 g ae ha^{-1}) post emergence to large, replicated, pastures that were either grazed or not grazed to determine how this low cost treatment could reduce medusahead abundance at management scale. We found that medusahead significantly lowered livestock production, but this decrease was significantly less than impacts often assumed by managers. We also illustrate that invasive plant impacts on gross agricultural profitability depend on livestock management decisions. For example, responding to a 10% increase in medusahead cover by shortening the grazing season reduced gross profitability 102.97 USD per hectare but responding by reducing animal density by selling animals early increased gross profitability 2.71 USD per hectare. Aminopyralid applied post emergence was a cost effect means to reduce medusahead cover at scale with medusahead cover decreasing from about 50 to 20%. Careful application timing was critical as just 12 d separated the least (jointing and boot stages) and most (boot to early flowering) effective timings for controlling medusahead. Medusahead has a negative impact on livestock production but in most cases, this can be mitigated with effective grazing management or low cost applications of aminopyralid.

Invasive Plants, Biological Control, and Wildfire: Why Integrated Invasive Plant Management Matters with Increasing Wildfire Risk. Carol Randall*; USDA Forest Service, Medimont, ID (150)

The US Forest Service's initiative "Confronting the Wildfire Crisis: A Strategy for Protecting Communities and Improving Resilience in America's Forests" calls for an unprecedented "paradigm shift" in land management to increase fuels and forest health treatments across jurisdictions to match the actual scale of wildfire risk to people, communities, and natural resources, especially in the Western United States. Weed managers recognize that before wildfire, weeds can be fuel; after wildfire, weeds can spread; and fuels and forest health treatments can exacerbate existing and create new weed problems. An integrated approach to addressing current and preventing future weed populations is vital when disturbance, like wildfire, and management activities, like fuels and forest health treatments, increase across the landscape. Integrated Pest Management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties; pesticides are used only after monitoring indicates they are needed according to established guidelines. Weed biological control was implemented on several noxious weed systems throughout the west over the past decades but weed biocontrol impacts are often unrecognized. In this talk Carol will discuss the need to recognize existing and establish new weed biological control programs across landscapes as a bulwark against more significant weed problems precipitated by disturbance and management. Weed biological control, alone or in conjunction with other weed management tactics, can reduce the impact weeds have across a disturbed landscape.

Revegetation Following Wildfires. Jane Mangold*; Montana State University, Bozeman, MT (151)

Seeding desired vegetation, commonly called revegetation, is often implemented after wildfire to limit weed invasion and reduce soil erosion. Establishing desired vegetation from seed is prone to failure, and there are many aspects of revegetation that should be considered to ensure the highest likelihood of success. This presentation will discuss considerations for determining whether revegetation is necessary based on weed abundance prior to the fire and fire severity. Generally, areas with high weed abundance prior to the fire and areas that burned severely should be prioritized for seeding. Additionally, areas disturbed through fire suppression activities, e.g., fire breaks, should be prioritized. Key steps of a revegetation plan will be presented including seed bed preparation, weed control, designing a seed mix, broadcast versus drill-seeding, timing of seeding, follow-up management, and long-term monitoring. The presentation will also discuss pros and cons of revegetation following wildfire, drawing upon published literature from the western U.S. that suggests revegetation can have lasting impacts on vegetative composition.

Fuel Break Post-Fire Vegetation Recovery in Southern California Shrubland. Loralee Larios*[1], Noah Teller[2], Erin McCann[2], Janet Franklin[2], Marko Spasojevic[2], Nicole Molinari[3]; [1]University of California, Riverside, CA, [2]University of California-Riverside, Riverside, CA, [3]US Forest Service, Goleta, CA (152)

Wildfire can create conditions that provide an opportunity for invasive plant species to establish and spread, and firefighting in natural areas may exacerbate this risk. Areas like fuel breaks, where soil is disturbed and plant material is completely removed, provide ideal conditions for many invasive species. Unintentionally firefighting equipment may increase invasion potential by redistributing seeds of invasive species to and throughout these areas. Reducing this invasion potential is of the utmost importance to minimize type conversion of native shrublands to invasive annual grasslands. Here we will talk about the extent to which fuel breaks create habitat suitable for invasion by reviewing plant community recovery in fuel breaks in two southern California fire scars (Powerhouse fire, 2013 and Canyon fires 2017). We will also review results from a post-fire fuel break experiment designed to identify the effectiveness of mowing and seeding as potential management strategies to minimize the establishment of invasive species. The association between fuel breaks and invasion appears to be highly context dependent, and further research to identify the length of time of management actions can help improve the efficacy of post-fire invasion management.

DISCUSSION SESSIONS

Project 1 Discussion Session: Pasture, Range, Forestry, and Natural Areas

Moderator: Will Hatler

Notes prepared by: Lisa Jones

Discussion Topic: New, emerging, or existing problem weed species: Where are the research gaps?

- A USFWS employee asked the group about research gaps as they have gotten a large amount of funding for annual grass and fire projects
- How much existing native species is sufficient to spray indaziflam?
  - Try a test strip first
  - Collect soil and germinate seeds to see what is in the seed bank
- For some, big areas of bare ground after using indaziflam is scary. This occurs in highly degraded sites.
- Prescribed burning allows for a longer indaziflam residual at lower rates since more herbicide hits the ground instead of being intercepted by thatch. But higher herbicide rates do fine when plant residue is present.
- We don't know what happens to indaziflam if you spray it and then the area burns
  - Do you need to wait until fire risk is gone to spray indaziflam, or can you spray it in summer?
- We need more information on native species seed longevity in the seed bank
- Gaps in knowledge of seed bank dynamics, especially percent germination based on precipitation
- How much of the seed bank (native and non-native species) is killed with indaziflam?
- Monitoring of seeds banks is needed with some "life-support" actions outlined so that we don't lose native species
- How quickly do we need to act (with herbicide and/or seeding) after a fire?
- How long do herbicide treatments last at the landscape scale?
- Priority to treat less degraded/higher value sites
- Fuel breaks in low, dry areas have reduced fire impacts by about 50%
- After herbicide treatment, what's next? We need longer term evaluations, especially for forbs and species richness. We also need a plan for re-treatment if weeds return.
- We will always have questions, so at what point is there enough information for the DOI/BLM to approve the use of indaziflam for annual grass control?
- Opportunities to do herbicide impact studies (on more than the target weed) are limited
- Why do some indaziflam treatments last only 2 years and others last for 5 years?
- We need more information about why an herbicide treatment works in some areas and not in others—why do sites respond differently?
  - We often do not discuss land use/disturbance history, which may impact efficacy
- However, this information is not always available

- A whole-systems approach was suggested since western US habitats are highly variable and many studies are site-specific
- The high heterogeneity in rangelands means broad training in ecology, plant biology, and weed science is needed
- Not many papers use multiple types of weed control, so more integration would be valuable
    - Herbicides and biocontrol methods are not mutually exclusive
- Invasive forbs have taken a back-burner to annual grasses. Leafy spurge is an existing problem that we are still dealing with.
    - There are limited tools for controlling leafy spurge in wet areas
- Rush skeletonweed is spreading and herbicides are not working
    - Potential agronomic impacts (currently it is a problem in Australia), so there is an opportunity to raise awareness and get commodity groups involved
- Cutleaf vipergrass is easily controlled in range (in Utah), but not in alfalfa, so there is opportunity to reach out to stakeholders to be on the lookout for this emerging problem weed
- There is also a lot of completed research in filing cabinets that needs to be published

Also in this session: Rachel Seedorf was chosen as the 2023 section chair-elect.

Chair 2022:
Will Hatler, Corteva, Meridian, ID
william.l.hatler@corteva.com

Chair-Elect 2023:
Lisa Jones, University of Idaho, Moscow, ID
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Chair-Elect 2024:
Rachel Seedorf, Aero Applicators, Inc.
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List of Attendees not available.

Project 2 Discussion Session: Weeds of Horticultural Crops

Moderator: Marcelo Moretti, Oregon State University

Topic: *The Future of Online Extension Resources in Horticultural Crops.*

The Weeds of Horticultural Crops Section had ten paper presentations in 2022, and all presentations were well attended, ranging from 20 to 45 participants. The discussion session was held on Wednesday, March 9, from 3:30 to 4:45 pm PT. The topic was *The Future of Online Extension Resources in Horticultural Crops*.

The moderator began the discussion with a short presentation outlining existing online extension resources such as the Pacific Northwest Weed Handbook, the University of California IPM website, and North Dakota State University extension publications. These extension resources provide herbicide recommendations and provide less information on non-chemical options. Also, these are laid out as printable fact sheets with few interactive platforms for users. The challenges identified for the continuation of the extension publication model were dwindling resources to create and maintain online material that quickly becomes outdated, the human capital loss caused by retirement in positions consolidating research and extension across all land-grant institutions, difficulty in providing integrated weed management recommendations as Western US agriculture is quite diverse, and few innovations in the delivery of technical information. The presentation ended with a question on the path forward for extension information dissemination, including consolidation of extension efforts across states and how to pursue new funding models for extension activities.

The discussion was initiated with a question on the number of visits that some of these online materials have yearly. Dr. Ronald Edward Peachey pointed out that the PNW weed handbook has over twenty thousand annual visits. At that point, a comment was made that consolidating effort is nearly impossible because of the lack of personnel and crop and regulatory diversity across the regions represented at the meeting. At the same time, new information must be generated to address the information gap in the online material. Kai Umeda shared his experience using the informal virtual presentation of field experiments, noting that this type of presentation may have more engagement with viewers but cannot deliver in-depth recommendations. The WSWS progress report, combined with the online presentation of research reports, was suggested as a source to share information.

Examples of private extension resources were discussed, such as the AGPhD. The general comment was that AGPHD is successful because its clientele receive needed information via a site that is supported by advertising. Many other ideas were discussed, including new formats to present data. However, we could not identify a clear path forward to address the current challenges.

At the end of the discussion session, Dr. Jose Luiz Carvalho de Souza Dias was selected as the chair-elect for the 2023 meeting, which will lead to his being named the Horticulture chair in 2024 in Denver, CO. Elizabeth Mosqueda will serve as the Weeds of Horticultural Crops chair for the 2023 meeting in Boise, ID.

Chair 2022:
Marcelo Moretti, Oregon State University
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Chair-Elect 2023:
Elizabeth Mosqueda, Madera Community College
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Chair-Elect 2024:
Jose Luiz Carvalho de Souza Dias, University of Arizona Cooperative Extension
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Attendees:

Name	**Affiliation**
John Roncorroni	UCCE
Sonia Rios	UCCE
Elizabeth Mosqueda	Madera Community College
Jose Luiz Carvalho de Souza Dias	University of Arizona Cooperative Extension
Cody Zesiger	Utah State University
Kai Umeda	University of Arizona
Harlene Hatterman-Valenti	North Dakota State University
Marcelo Moretti	Oregon State University
Roger Batts	North Carolina State University
Ed Peachey	Oregon State University

Project 3 Discussion Session: Weeds of Agronomic Crops

Moderator: Nevin Lawrence, University of Nebraska, Scottsbluff

Topic: *Supply Chain Disruptions and Herbicide Shortages, How Will Weed Control Differ in 2022?*

*Meeting minutes are not "verbatim" but serve as a general overview of the discussion.

Alix Whitener was elected as Agronomy Section Chair-elect for 2023 and Chair in 2024.

The session began with a discussion of popular new articles regarding glyphosate shortages and a concern among many farmers about availability and pricing of glyphosate. Currently in ND, glyphosate prices are double what they were last year.

Pesticide manufactures believe there will be enough of most products, but they will be shipping the products to areas of the country that will be making applications first. Consequently, products will only be available at the time they are needed, and difficult to get weeks in advance. This method of delivery may become impacted if producers try and hoard products. A lot of producer response to pesticides this year may be similar to the great toilet paper shortage of 2020.

Glufosinate may be limited in 2022, and prices for glufosinate will be higher. BASF is prioritizing acres where alternatives to glufosinate are limited, like canola.

Some shady distributors seem to be playing on producer fear while selling generics. This includes "snake oil" selling where farmers are promised they can cut use rates in half through the use of special additives. Growers needs to remember to follow label recommendations if they want to cut rates, which generally requires applications to very small weeds to ensure adequate control.

Current recommendations to farmers should follow standard herbicide best practices. Focus your inputs into PRE products as POST options may be the most limited. Corn has plenty of options, so products that may be limited, like glyphosate and glufosinate, should be used in other crops. However, in some crops focusing on PRE applications may lead to an inability to replant if crop loss occurs do to frost.

Everything in 2022 will be difficult. Supply chain shortages will be a bigger issue than just herbicides, pesticides and fertilizer supply may also be tight in 2022. However, as AG inputs go up, AG prices should offset those costs for farmers.

Research Progress Report notes

Vanelle Peterson discussed the use and the decreased output of Research Progress Reports at WSWS.

- Currently accessing old reports is very difficult and they are not searchable.
- The time when submissions are due is inconvenient.
- There isn't a lot of value, for researchers, to submit reports.
- There are journals in both Entomology and Plant Pathology for submitting research reports. That may present an incentive for researchers to prepare more reports.

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Chair-elect 2023:
Steve Valenti, Bayer Crop Science
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Chair-elect 2024:
Alix Whitener, FMC
alix.whitener@fmc.com

Attendee		**Email**	
Nevin	Lawrence	nlawrence2@unl.edu	2022 Chair
Alix	Whitner	alix.whitener@fmc.com	2024 Chair-Elect
Harlene	Hatterman-Valenti	h.hatterman.valenti@ndsu.edu	2022 Note Taker
Joe	Ikley	josephikley@ndsu.edu	
Caleb	Dalley	caleb.dalley@ndsu.edu	
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Neha	Rana	neha.rana@bayer.com	
Clint	Beiermann	clint.beiermann@montana.edu	
Greg	Dahl	gkdahl@landolakes.com	

Project 4 Discussion Session: Teaching and Technology

Moderator: Jeanne Falk Jones

Topic: *Learning from the Past to Improve the Future of the Teaching and Technology Transfer*

In the Teaching and Technology Transfer meeting, there were 14 members present. The discussion started out with slides summarizing 'Learning from the Past to Improve the Future of the Teaching and Technology Transfer'. We looked at the words that described the past/current state and the future hopes for Extension.

The discussion then moved to what should be covered in the 'Teaching and Technology Transfer' section. Many folks discussed that this section should be focused on how to extend scientific concepts to our audiences (i.e., How do we teach hard/difficult to understand topics? How to we use social media to share research findings?) The challenge is that those type of talks are not as 'valued' as scientific talks where we share research findings. These topics are important though, because we (as Extension educators) learn from each other on communicating and demonstrating difficult weed control concepts.

The question surfaced on how we recruit members/talks into our section? Also, where do folks fit in the society that are focused on technology/robotics/automated weed control? Do they fit in 'Teaching and Technology Transfer'? Basic biology? Agronomic Crops? There were no definitive answers on these questions, but general thoughts expressed. These topics are going to be further discussed at the board meeting.

Kirk Howatt volunteered to be the incoming vice-Chair (Chair in 2024).

By Jeanne Falk Jones, K-State Multi-County Agronomist (vice-Chair for 2022).

<u>Chair 2022:</u>
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<u>Chair-elect 2023:</u>
Jeanne Falk-Jones, Kansas State University
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<u>Chair-elect 2024:</u>
Kirk Howatt, North Dakota State University
kirk.howatt@ndsu.edu

List of Attendees not available.

Project 5 Discussion Session: Basic Biology and Ecology

Moderator: Rui Liu

Topic: *Emerging Tools for Ecological Management of Weeds and Herbicide Resistance*

Notes: About 12- 15 people attended the discussion. We went through the slides prepared by Adewale Osipitan on the different tools for ecological management of weeds and herbicide resistance, such as solarization/ bio-solarization and harvest weed seed control for managing weed seedbank, manipulation of the sex distribution of weed populations, etc.

Here are some specific discussion points:

Weeds moving into rangeland is a problem

- Crop/ natural area weed management has different focus
- Is there any way to not kill but to use other ways to prevent? If some species are killed, other kinds will take over the place. Ask the question of "what comes next if we get rid of the current problem"?
- Crop to rangeland (e.g. cheatgrass) differences: Rangeland and natural areas are not in need to concern about yield. But crop production needs to hurry to control the weed before harvest.
- Technology such as seed destructor works when the seeds can get into the destructor. But if seeds shatter and don't get in there. It's no use… but it's good to have as one tool in the toolbox
- Some methods can provide 95% control, what happens to the rest 5% matters. Managing the 5% is important. For example, kochia, we manage but it comes back every year. What else can be done to prevent the kochia going into seed? The 5% kochia not controlled may produce a large number of seeds. Mesgaran and Wu et al. at UC Davis are working on the manipulation of weed sex distribution. This maybe a way to prevent seed production.
- Limitation of tools and manpower to do mechanical weeding and mange herbicide resistant weeds in rangeland areas. Flying drones and use the technologies could be of help.
- New management practices -flaming, smart weed control, etc. how far are we from precision weed control? Going back to IPM solutions. Some areas may not be able to use smart technologies. In Australia, development of machine that identify weeds, do spot spray and cultivating crops- but this can't be used in a large-scale land due to the expensive cost.
- Flaming, laser technologies -challenge: 5- 10 thousand areas are not feasible. How much area can the technology cover?
- In North Dakota, two-year crop rotation is practiced. Resistant kochia, waterhemp, grass species (wild oat, green foxtail). Sometimes resistant to one group of herbicides, but not to the other group. Rotating chemistry is important. Increase the rotation from two year to three year or five-year rotation may help in dealing with resistance, e.g. annual/ perennial, fall planted/ spring planted crops etc. increase seeding rate, cultural practices. Use of cover crops- Dr. Anita Dille's student use triticale + other cover crops to reduce kochia density 80% is significant. Oct- April in North Dakota is frozen, apply flumioxazin in fall (as late as possible) can reduce kochia populations up to 70 to 80%. When you reduce kochia to 20 to 40%, then come in with spring burndown, it's easier to manage. Combination of cover crop and herbicide treatments can increase the control of kochia up to 90%. Incorporating termination

timing of cover crop is key, depending on what crop going into. If trying to maximize the yield, cover crop is not a good option, but it is good to use cover crop to reduce herbicide usage and increase organic matter and reduce soil erosion. There is tradeoff with moisture- eastern part of North Dakota and Kansas uses cover crops more often.

- In Midwest, most corn and soybean, diversifying crops is important, as well as recommending growers to use mixtures, which can delay resistance to 10 -20 years. E.g., roundup doesn't work anymore.
- There is challenge for growers to adopt the suggestions. Growers tend to rely on single chemistry and don't think about resistance issue. Growers want to see numbers, if they can't see the resistance causing problems, they tend to not change.
- Growers' management practices will cause consequences to their neighbors, and rangeland (non-crop land) areas. It's hard to convince growers to spend money to manage resistance. Most growers rent lands nowadays. They won't think about the ones after them after they retire from the land. The younger generation is invested in the previous generation but if people are renting lands, then they won't care much. Good neighboring farmers are critical.
- E.g., in boulder county, famers rent land from the county. Maybe putting in the lease about management resistance? Resistance is a slow process. It's tricky to put into agreement. Some farmers exchange lands, it's possible to have agreement on managing resistance. But if someone is renting land for short lease (one to two years/ seasons), it's not possible. Complicated but keep "preaching" … it's like renting a car…
- Tradition and economic reality- there is a generational change. Curiosity about the change over different generations. Looking into the future and see what is good in 10 years v.s. short terms.
- Question: can you force people to manage weed species? – only if it's noxious weed. Kochia isn't one of them. In North Dakota, most noxious weeds are in rangeland or non-crop land, very few on the list for crop land.
- Seed producer in crop land must go through commission (in Idaho) to get approval for listing a weed species as noxious weed. May not be practical.
- Bridge the gap in between of applied weed science and weed biology and ecology: IPM- integrated pest management methods. E.g. (1) drones may not work in some situation, how about bees? Integrating flower pollen and bees -let bees carry the sterilized pollen to the weeds. (2) Cover crop may not give you 100% control but it will reduce weed size at the time of application. There is no silver bullet. Doing small things- diverse the cropping systems, suppress weed, rotational crops can all help. Do illustrations in rangeland for growers on using cover crops, grazing, etc.
- Will rapid identification of herbicide resistance in weeds (like rapid covid test) help the growers realize the problem? Need to be cautious about the method. People are different. Surveys may help knowing the problem as well. Sometimes the weeds collected might not be very resistant. Need to be careful about assuming the plant is resistant. The level of resistance in the weed population may differ among different populations, result could be misleading if only based on the plant or population.

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Chair-elect 2024:
Alex Ceseski, University of California
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List of Attendees not available.

Discussion Session: Education and Regulatory

Moderator: Carl Coburn

Topic: *How do we Increase Attendance and Involvement from Agency People?*

The session focused on this question. Below are comments/suggestions aimed at addressing the question as well as two action items. A list of participants follows. Finally, there are several questions that were posed by presenters during the Education and Regulatory session. These questions were not addressed during the discussion session but may be considered in the future.

Would digital aspect improve their involvement? Digital offerings would limit participation from industry because it would be difficult for them to get approval to travel.

One idea would be to bring a focus group together to ask them what WSWS can do to serve them. Shared experience of past where Tom Whitson brought together a group of managers and had them present a poster at the conference. Something like this would have to be in operating procedures to keep it going longer term than a one-and-done.

Go to each Forest Service and BLM office and ask them to commit to a Zoom meeting for a facilitated discussion about how WSWS can serve them.

We need to ask them what we can do to serve them.

Record meetings and make them available for viewing after conference; someone would still have to register for meeting to have access to them. Would have to address industry and even non-industry presentations that may not want to be available long-term; would have to withdraw those from digital archive. Other opinion that people probably wouldn't watch them after the fact so maybe not that effective.

WSWS liaison to agency people. This would have to be really well thought-out so agency would allow liaison into inner circle for discussions. This would be something board could consider.

Where are we going to be over the next year? While there, have a locally relevant symposium or workshop or even Education and Regulatory session, similar to what was done with history session this year.

Need to have meetings where the agency and ag people are instead of choosing meeting locations based upon hotel amenities.

Local aspect of conference that may or may not be closely related to main discipline of society. Can we add a local flair to each of the Project Areas as a way to draw more local managers to the area?

Focus group discussions with key people, perhaps grouped by 3-4 state regions and have several of them over the course of the year.

Who are we talking about when we talk about "Agencies"—anyone county, state, federal, anyone not academic or industry?

European weed science research groups—meet every 2-3 years, make sure to have fun, be more careful about where we have these meetings and what we do to see diversity of agriculture and draw in relevant audiences for a specific region, e.g., if meeting is in Idaho or Oregon, focus on forestry; if in Wyoming or Montana, rangeland.

Also need to think about broadening the definition of "industry"; it's not just herbicides but start up technology companies and the like.

Need to think about format for conveying the research presented at WSWS as most talks would be too dense for many managers. Can 3-minute video contest help with this?

Should there be a larger membership committee? If so, define objectives to keep them focused on agency/industry.

Need to move out of our comfort zone.

If we have value, we have people. Aim is to provide value not just increase membership. Membership follows value. We need to do something different, e.g., focus on technology and think outside the box.

Question was asked about how much does this society ensure money allocated at federal level is being spent on the ground? As a non-profit agency, we cannot lobby. We can be an information source if asked, but we cannot say where money should be spent.

Action item: Would board consider creating an ad-hoc committee to take ideas from this discussion and put some structure to them to approach new membership, focused on agency. Potential co-chairs include Todd Neel, Julie Kraft, Tim Prather. Incoming Education and Regulatory Chair Jane Mangold would be involved too.

Action item: Would board consider revising operating procedures to include, within duties of Education and Regulatory Chair, to actively solicit local, relevant weed-related issues as candidates for Education and Regulatory section, symposia, workshop, or tours.

Other questions posed during presentations but not discussed:

- Should discussion sessions be continued?
- Should the research progress reports be continued?
- What new charged does WSWS need to address possible new members or needs of current members?
- How can WSWS attract new members?
- Should WSWS meet more regularly with other societies?
- Should society try to increase student participation, and if so, how?
- Weed Science education: Is it possible to agree on the most fundamentals of education?
- How do we bridge a divide that seems to be getter broader between basic and applied?
- How do we maintain industry membership and involvement in the future, considering consolidation?
- How does WSWS work more with those outside society and outside the West?

Chair 2022:
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Chair-elect 2023:
Jane Mangold, Montana State University
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Name	**Affiliation**
Grace Ogden	Oklahoma State University
Marty Schraer	Syngenta
Joan Campbell	University of Idaho
Lesley Beckworth	Teton County Weed and Pest, Wyoming
Julie Kraft	Sublette County Weed and Pest, Wyoming
Andrew Kniss	University of Wyoming
Dirk Baker	Campbell Scientific
Connor Ferguson	Sesaco Corporation
Phil Westra	Colorado State University
Vanelle Peterson	WSWS ad hoc history committee
Phil Banks	Marathon Agric. Consulting
Jill Shroeder	New Mexico State University
Steve Fennimore	University of California-Davis
Sandra McDonald	Mountain West PEST
Carol Mallory-Smith	Oregon State University
Tim Prather	University of Idaho
Carl Libbey	WSWS Proceedings and Newsletter editor
Joe Yenish	Corteva Agrisciences
Roger Gast	Corteva Agrisciences
Carl Coburn (Chair)	Bayer
Jane Mangold (Chair-elect, note taker)	Montana State University

WESTERN SOCIETY OF WEED SCIENCE NET WORTH REPORT

April 1, 2021 through March 31, 2022

ASSETS	
Cash and Bank Accounts	
American Heritage Checking	$35,259.98
American Heritage Money Market	$58,207.40
CD#3	$25,463.95
CD#4	$25,351.23
CD#5	$25,000.00
CD#6	$25,603.60
CD#7	$25,730.26
TOTAL Cash and Bank Accounts	$220,616.42
Investments	
RBC Dain Rauscher Account	$210,346.05
TOTAL Investments	$210,346.05
TOTAL ASSETS	$430,962.47

WESTERN SOCIETY OF WEED SCIENCE CASH FLOW REPORT

April 1, 2021 through March 31, 2022

INFLOWS ($)	
Annual Meeting Income	89,848.43
Interest Income	410.31
Dividend Income	3,618.90
Membership Dues	8,200.74
Rita Beard Endowment	75.00
Royalty for Proceedings - RPR	1,051.99
Security Value Change	31,971.77
Student Travel Account	1,100.00
Sustaining Member Dues	11,800.00
TOTAL INFLOWS	**148,077.14**
OUTFLOWS ($)	
Annual Meeting Filing Fee	20.00
Annual Meeting Expense	5,334.39
Mobile Meeting App	29,223.00
Total Annual Meeting Expense	**34,557.39**
Bank Charge	1,826.03
CAST Annual Dues	1,500.00
Copies	150.00
Director of Science Policy	12,423.00
Fee Charged	2,083.67
Insurance	525.00
Management Fees	23,058.40
Miscellaneous	821.60
Mobile Deposit Fee	72.50
Proceedings/Publications	750.00
Postage	11.90
Summer Meeting	1,358.93
Student Awards	3,818.03
Taxes	365.00
Travel to Summer Meeting	419.10
Travel to WSWS Meeting	1,500.00
Virtual Terminal Fee	812.55
Social Media	1,000.00
Web Site Hosting	4,000.00
TOTAL OUTFLOWS	91,073.10
OVERALL TOTAL	$57,004.04

WSWS 2022 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.

Andrew Kniss, University of Wyoming

Dr. Andrew Kniss is a Professor of Weed Science and Head of the Department of Plant Sciences at the University of Wyoming. His basic and applied research is focused on sustainable weed management in the diversified agronomic cropping systems of the region. Andrew has been a very active member in the WSWS since 2004, initially as a graduate student and currently as a major professor advising his own students who regularly participate in WSWS activities. Dr. Kniss' publication record includes more than 50 peer-reviewed research papers, nearly 200 abstracts in conference proceedings, and several extension bulletins and crop production guides. Andrew has also made important contributions to our discipline through his efforts related to developing and optimizing statistical analyses; some of these publications, manuals, and software packages are sure to be widely used by generations of weed scientists in the WSWS and beyond. Andrew has provided extensive service and leadership to the Society, including the presidential rotation (serving as president in 2019), the board position of Research Section chair, and as a chair or member of several other committees. Beyond WSWS, Andrew has a similar level of service commitment to the WSSA, including serving on the Board of Directors, as an Associate Editor for Weed Technology, as well as on numerous standing and ad hoc committees. Andrew combines excellence as a scientist and leader with personal humility, collegiality, and good humor.

Richard Zollinger, AMVAC Chemical Company

Dr. Richard Zollinger is the Northwest Region Product Development Manager for AMVAC Chemical Company. Although Richard's career has included several productive years in academia with North Dakota State University, he started his career in the private sector and he has returned to the private sector. Dr. Zollinger has exceptional ability to conduct relevant, high-quality research and energetically distribute the results to scientific or lay audiences with similar ease. The findings are important for growers to achieve optimum profitability with a solid foundation in the core of chemistry and biology. He understands how to reach his audience and promote their understanding of difficult concepts through practical examples. Dr. Zollinger's expertise in adjuvants has commanded high demand for his presentations in the United States and abroad. Richard was North Dakota's liaison to the IR-4 program and also drafted many Section 18 registration requests to benefit growers. Now he continues to promote grower access to proper use of herbicides through registration efforts with herbicides at AMVAC. Dr. Zollinger is an exemplary ambassador for agriculture and a keen proponent of weed science understanding and activities for the improvement of growers and promotion of the Ag Industry. In addition, the merits of his service to the WSWS and other professional societies place him in high regard among peers and clientele. He seeks to promote and encourage others either in collaboration or respect for their individual academic pursuits.

WSWS 2022 HONORARY MEMBER

Hugh Beckie, University of Western Australia, Perth, Australia

Dr. Hugh Beckie is the Director of the Australian Herbicide Resistance Initiative and a Professor in the School of Agriculture and Environment at the University of Western Australia. He is widely recognized as an herbicide resistance expert in the weed science industry. He has been an invited speaker at over 50 international conferences or workshops, 200 regional or national conferences or workshops and made more than 150 media contributions throughout his career.

In addition to the large impact that Dr. Beckie has had from his work alone, he has also had a huge impact through mentorship, supervision, and teaching. He has served as a supervisor or committee member for 33 undergraduate and graduate students, as well as a post-doctoral fellow. One of his most significant impacts has been standardizing field survey methodologies to monitor and identify herbicide resistant weeds. These methods have since been adopted elsewhere, including in the western US. In western Canada these methods have been used to monitor for herbicide resistant weeds over time as well as developing a prairie-wide resistance testing survey. He was the first researcher globally to quantify the risk of resistance selection in weed populations from various crop management practices through combining field management data and the occurrence of resistance. The methodologies and research he has conducted have been emulated and replicated not only across western Canada, and the western United States, but across the globe.

WSWS 2022 OUTSTANDING WEED SCIENTIST AWARDS

Outstanding Weed Scientist, Early Career: Charles Geddes

The Outstanding Weed Scientist, Early Career was awarded to Charles Geddes. Dr. Charles Geddes is a research scientist in Weed Ecology and Cropping Systems for Agriculture and Agri-Food Canada in Lethbridge, Alberta. He received his B.Sc. in Agroecology in 2012 and his Ph.D. in Plant Science in 2018, both from the University of Manitoba. He began his position with AAFC in 2017. Dr. Geddes is a highly in demand speaker in Canada for the research he conducts on herbicide resistance monitoring and status, weed biology and ecology, as well as applied management of weeds in western Canadian cropping systems. He has published or submitted 27 peer reviewed papers, 6 book chapters, 5 government publications, and 43 fact sheets/papers/extension documents. He has given 73 oral presentations, 19 poster presentations and been cited in the media or popular press on 64 occasions. He has a large, vibrant and diverse research program, while also serving in management and various scientific societies and organizations. He has only been a member of the Western Society of Weed Science for a few years but is already active during conferences through giving presentations and posters, and is currently the past chair of the Public Relations Committee. It is clear from his CV and his accomplishments to date that he is a scientist set on making an impact in our industry and is on a trajectory to easily meet those goals. One person that wrote a letter of support stated: What makes Dr Geddes stand out is how effectively he speaks to any audience. He can speak as fluently to a technical audience as a room of farmers. He captivates and engages his audience and delivers the most relevant information. This is a rare talent even among the top of our discipline, and often one that takes years to develop and refine. This is innate that will allow him to reach great heights in terms of the contributions he will make to weed science. I have been incredibly impressed with his creativity, professionalism, energy and passion. He is a gifted young scientist and has the impact and accomplishments that would be the envy of scientists many years his senior.

The Outstanding Weed Scientist, Public Sector

This award was not conferred in 2022

The Outstanding Weed Scientist, Private Sector

This award was not conferred in 2022

WSWS 2022 WEED MANAGER AWARD

The Weed Manager was awarded to Julie Kraft. Julie completed her B.S. in Rangeland Ecology at Colorado State University. She is so talented that while getting her Master's in Weed Science at Colorado State she ran the Exotic Species Inventory Database for the National Park Service. After he graduate work she was promoted quickly through several positions to arrive at her present position of supervisor at Sublette County Weed and Pest. She organizes numerous noxious weed workshops and is the most sought after speaker for field days showcasing her work in cheatgrass control. She collaborates extensively with academia and even mentors graduate students. She has developed her own monitoring and data collection program to track noxious weed treatments. She is active in several academic societies and has served on many WSWS committee and also on the board for WSWS, NA Invasive Species Management Assoc., Pipeline Committee, Society for Range Management, and the Wyoming Weed and Pest Council. She is viewed as the most active weed managers not just in Wyoming but in the entire western state region. She has captured millions of dollars in funding during her time in Sublette County to manage over 100,000 acres of cheatgrass. One person that wrote a letter of support stated of Julie: "Her project is the epitome of what a coordinated weed management effort should envision. I would not only urge but strongly recommend that you award committee members AND the entire WSWS membership spend time with Julie in Sublette County, Wyoming to experience first-hand what successful leadership in weed management should look like."

WSWS 2022 PROFESSIONAL STAFF AWARD

This award was not conferred in 2022

WSWS 2022 PRESIDENTIAL RECOGNITION OF SERVICE

Vanelle Peterson was honored with recognition of service to WSWS by leading the updating of the WSWS History. Vanelle brought the idea of updating 1938-1992 WSWS History from 1993 – 2021 to the WSWS Executive Committee in early 2020. We agreed that it was a wonderful idea and that if she was willing to lead it, we were "behind" her. Vanelle was the editor and Phil Banks, Rod Lym, and Don Morishita were co-editors. I do not think she or the rest of the committee were prepared for the amount of work. But they did a wonderful job and provided a valuable service to the WSWS.

WSWS 2022 PRESIDENTIAL AWARD OF MERIT

Mithila Jugulam, Todd Neel, Dennis Scott, & Mirella Ortiz

The WSWS President can "confer the Presidential Award of Merit, if in his/her opinion, a member of the Society has demonstrated distinguished service." I may have broken the rules a bit by conferring the 2022 Presidential Awards of Merit to the four core members of the 2021 WSWS Planning Committee.

· Mithila Jugulam (Research Section Chair)

· Todd Neel (Education & Regulatory Section Chair)

· Dennis Scott (Student Paper Judging Committee Chair)

· Mirella Ortiz (Student Liaison)

The work that each of them did to help to plan and execute a very successful WSWS meeting in the virtual format was amazing. I could not have done it without each of them. I know there are other members of WSWS who could have helped, but honestly, I cannot think of any other members that I would have trusted more or enjoyed working with more. We did it and we did it well. In fact, better than our members expected we could.

I am eternally grateful to each of them for the support, ideas, plain old hard work, and keeping it fun. Their dedication and service to WSWS is greatly appreciated and I wanted to acknowledge it to the entire society.

Sincerely,

Sandra K. McDonald
WSWS President 2021/2022

Mithila Jugulam

Todd Neel

Dennis Scott

Mirella Ortiz

WSWS 2022 ELENA SANCHEZ MEMORIAL STUDENT SCHOLARSHIP RECIPIENTS

Rich Zollinger, Awards Committee Chair announced the recipients of the "WSWS Elena Sanchez Outstanding Student Scholarship Program" were Jodie Crose: 3rd year Ph. D. candidate, University of Wyoming, Dr. Brian Mealor, Ednaldo Alexandre Borgato: 4th year Ph.D candidate, Kansas State University, Dr. Mithila Jugulam and Dr. J. Anita Dille, and Sachin Dhanda: 1st year Ph.D. candidate, Kansas State University, Dr. Vipan Kumar. A big thanks to their advisors for bringing along such great promising talent for the future of weed science.

Jodie Crose

Ednaldo Alexandre Borgato

Sachin Dhanda

WSWS 2022 RITA BEARD ENDOWMENT STUDENT SCHOLARSHIP

The Rita Beard Endowment Foundation Board of Trustees has selected Jodie Crose Ph.D. candidate and graduate student at the University of Wyoming as the travel award scholarship recipient for 2022. The Rita Beard Endowment Foundation is a 501 (c) (3) non-profit that was created from a generous donation from Rita Beard's family and friends to support students and early career invasive species managers with educational opportunities by providing registration and travel to professional meetings including: Society for Range Management, Western Society of Weed Science, Western Aquatic Plant Management Society and the North American Invasive Species Management Association. The awardees selected in fall 2022 will be attending professional society meetings in 2023. To read more about the Foundation, learn how to apply for the 2023 scholarships, or make a donation go to: http://www.wsweedscience.org/rita-beard-endowment-foundation/.

Jodie's Ph.D. research investigated the role of indaziflam and other grass-selective herbicides for annual grass control and use in native species restoration. In addition to receiving the 2022 Rita Beard Endowment award, Jodie also received the 2022 WSWS Elana Sanchez Scholarship. Jodie has presented her research at the WSWS annual meetings multiple times including a 1st place Poster (Range, Forestry and Natural Areas) and a 2nd place oral Ph.D. presentation (Range, Forestry and Natural Areas), at the 2022 meeting in California, a 1st place Oral Ph.D. presentation at the 2020 meeting in Hawaii, and a 3rd place oral M.S. presentation at the 2019 meeting in Colorado. She also served as the WSWS Student Liaison to the WSWS Board for 2021-2022. She has been a teaching assistant and adjunct faculty for several classes with Sheridan College and the University of Wyoming. Jodie is passionate about helping stakeholders with land management needs. Jodie will graduate in May from the University of Wyoming and has accepted a field scientist job with Corteva back home in Oklahoma.

Jodie Crose and Sandra McDonald

WSWS 2022 STUDENT PAPER AND POSTER AWARDS

There was a total of 53 oral and poster presentations entered into the student contest. These were divided among five oral sections and five poster sections. Due to its large size, the Agronomic Crops oral section was split into M.S. and Ph.D. participants. Forty-two members of the WSWS volunteered to judge the contest: Kirk Sagar, Brian Schutte, Marty Schraer, Caleb Dalley, Mirella Ortiz, Lovreet Shergill, Rui Liu, Ed Peachey, Clarke Alder, Elizabeth Mosqueda, Albert Adjesiwor, Stacey Swanson, Vipan Kumar, Rachel Zuger, Rachel Seedorf, Shannon Clark, Joe Yenish, Dan Beran, Kai Umeda, Rich Zollinger, Rafael Pedroso, Jacob Fischer, Jafe Weems, Connor Ferguson, Steve Fennimore, Greg Endres, Kirk Howatt, John Roncoroni, Kelly Backscheider, Lisa Rew, Caio Brunharo, Erik Lehnhoff, Ed Silva, Quincy Law, Byron Sleugh, John Madsen, Cody Zesigner, Tom Getts, Earl Creech, Clint Beiermann, Alix Whitener, and Josh Adkins. First, second, and third place was awarded to sections with 9+ participants. First and second place was awarded to sections with 5-8 participants. First place only was awarded to sections with 1-4 participants. The winners from each section were announced at the Business Breakfast and presented with their award check. First place winners also received a copy of *Aquatic and Riparian Weeds of the West* donated by Carol Mallory-Smith and Caio Brunharo. Plaques will be mailed to the winners at a later date. Contest winners for each section are listed below.

On behalf of the WSWS we thank all the students that put themselves out there and did the work to participate in this year's Student Contests. Here are the results as announced at the Business meeting Thursday morning.

Oral – Project 1-Weeds of Range, Forestry, and Natural Areas

1st place- Chloe Mattilio- University of Wyoming
Multispectral Satellite Remote Sensing for Leafy Spurge Mapping in Northwestern Colorado

2nd place- Jodie Crose- University of Wyoming
Relative Tolerance of Newly-Seeded Grasses, Forbs, and Shrubs to Indaziflam in Northeast Wyoming

Oral – Project 2 Weeds of Horticulture Crops

1st place- Deniz Inci- University of California
Simulated Off-Target Drift of Florpyrauxifen-benzyl in Orchards and Vineyards

Oral – Project 3- Agronomic Crops (M.S.)

1st place- Tyler Hicks- University of Wyoming
Effect of Winter Wheat Cover Crop Termination Time on Dry Bean Production

2nd place- Ryan Johnson- University of Wyoming
Cover Crop and Herbicide Combinations for Season-Long Weed Control in Dry Beans

Oral – Project 3- Agronomic Crops (Ph.D.)

1st place- Grace Ogden- Oklahoma State University
Sweep Tillage Impact on Tumble Windmill Grass

2nd place- Liberty Galvin- University of California
Utilization of Pre-emergent Oxyfluorfen to Control Weedy (Red) Rice (Oryza sativa Spontanea), an Emerging Chemical Control Option for California Rice Producers

Oral – Project 5 Basic Biology and Ecology

1st place- Joe Ballenger- University of Wyoming
Shade Avoidance Alters the Root Architecture of Sugar Beets

2nd place- Albert Kwarteng- University of Idaho
Transgenerational Effect of Weed Competition on Wheat

Poster – Project 1 Weeds of Range, Forestry and Natural Areas

1st place- Jodie Crose- University of Wyoming
Sagebrush Tolerance at Various Growth Stages to Four Annual Grass Herbicides

2nd place- Mariana Amaraol- Washington State University
Genome Wide Scan for ALS Resistance in Bromus tectorum

Poster – Project 2 Weeds of Horticulture Crops

1st place- Andres Contreras- University of California
Use of Preemergence Herbicides in California Orchard and Vineyard Systems

Poster – Project 3 Weeds of Agronomic Crops

1st place- Sachin Dhanda- Kansas State University
Multiple Herbicide-Resistant Kochia in the Southcentral Great Plains: Field Survey and Management

2nd place- Milos Zaric- University of Nebraska-Lincoln
Industrial Hemp Biomass Negatively Affected by Herbicide Drift from Corn and Soybean Herbicides

3rd place- Victor Ribeiro- Oregon State University
Herbicide Resistance to Downy Brome from Fescue Fields in Oregon

Poster – Project 5 Basic Biology and Ecology

1st place- Crystal Sparks- Colorado State University
Glyphosate Induced Phytohormone Response in Rapid Necrosis Biotype of Giant Ragweed

Poster – Undergraduate Competition

1st place- Felipe Bagnara- Colorado State University
Cross-resistance of Conyza spp. To Auxinic Herbicides

Submitted by Josh Adkins – Chair, Dennis Scott, Clint Beiermann, and Prashasti Agarwal
Student Paper Judging Committee

WSWS 2022 ANNUAL MEETING NECROLOGY REPORT

At the Thursday business meeting, the WSWS members who passed away this year were honored with a moment of silence. Those members were:

Richard 'Dick' Comes

Richard 'Dick' Comes passed away on September 27, 2021 in McMinnville, Oregon, surrounded by his children and their families. Dick was just 1 ½ months shy of his 90th birthday when he died. Dick was born in Nisland, South Dakota on November 16, 1931. When Dick was a small child, his folks moved the family to Bonneville, Wyoming a very small community in Central Wyoming. Dick attended school in nearby Shoshoni and graduated from high school in 1949. After high school, he joined the US Navy and served on the LST 855 Kent County tank landing ship during the Korean Conflict. During the time he served in the Navy, Dick met the love of his life, Carleen Compton. They were married on September 16, 1954 and spent 58 happy years together. Dick and Carleen had two daughters, Joni and Lona. Later they adopted a son, Dan. Carleen passed away in 2012. Dick and Carleen are buried in McMinnville, Oregon.

Dick attended the University of Wyoming, earning his bachelor's degree in Vocational Agriculture in 1958. He continued on at UW and earned his master's degree in Plant Science in 1960. Dick then accepted a position as a Research Agronomist with the Agriculture Research Service, USDA in Laramie, Wyoming. In the 1965, Dick was transferred to Prosser, Washington to continue his work on aquatic and ditch bank weed management as a Research Plant Physiologist with ARS-USDA. In the fall of 1965, Dick attended graduate school at Oregon State University majoring in Weed Control in the Farm Crops Department. He received his Ph. D. from Oregon State University in 1971.

Between 1975 and 1979, Dick served the Western Society of Weed Science as Research Section Chairman, Secretary, Vice-President and President. He was elected Fellow of WSWS in 1983. Dick also served on numerous committees and chairmanships for the Weed Science Society of American and was a member of the review board of the Weed Science Journal. Dick was elected Fellow of WSSA in 1986.

Dick retired from ARS-USDA in December 1989. In his retirement Dick first and foremost enjoyed spending time with his family and friends. Dick never met a stranger because in five minutes they were a good friend.

Doug Ryerson

Doug Ryerson passed away March 6, 2022. Doug grew up in Bozeman, Montana where he earned his B.S. in Agriculture Science from Montana State University. Doug went on to earn is M.S. and PhD. in crop physiology from the University of Wisconsin, Madison, then went on to work as an area crop specialist for the University of Idaho before going to work as a Product Development

Specialist for Monsanto. He has a long history with Monsanto, where he made a concerted effort to improve crop production through better weed control specifically in cereals. Throughout his career he actively served the WSWS in many capacities including Past President, President, President-elect, Secretary, moderator for the Agronomic Crops Section, and participated in the student educational enhancement program. Doug will be remembered for his participation at WSWS but mostly as a husband, father, and a friend with a kind heart.

WSWS 2022 ANNUAL MEETING RETIREES REPORT

Since the last meeting, a total of five members of the society was brought forward as new or soon to be retired from the Western Society of Weed Science. The members were formally recognized at the Business Meeting. Their attendance, years of service, and professional leadership will be greatly missed.

Roger Gast, Discovery Strategy Leader, Corteva Agriscience

Tim Harrington, Research Forester, USDA Forest Service PNW

Scott Nissen, Professor, Colorado State University

Ed Peachey, Professor, Oregon State University

Phil Westra, Professor, Colorado State University

Submitted by Corey Ransom, Immediate Past President

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