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ARS Weed Science

Research News and Highlights

WINTER 2023

AREA – RESEARCH UPDATES

NORTHEAST

Rangelands and grasslands comprise 30 percent of land cover in the United States and are challenging environments in which to manage invasive weeds; costs are estimated at $6 billion annually. Common crupina (*Crupina vulgaris*) infests thousands of hectares of grasslands in Idaho, California, Washington, and Oregon degrading native and beneficial plant communities and reducing rangeland forage productivity. Dr. Matt Tancos, research plant pathologist at the ARS Foreign Disease-Weed Science Research Unit in Frederick, MD, is leading a team that is conducting research and performing regulatory reviews on the host-specific fungal pathogen *Ramularia crupinae* for common crupina. Field releases have been approved and ongoing studies are being conducted in the western United States. By combining the biocontrol pathogen with other tactics, rangelands will benefit from reduced populations of common crupina.

MIDWEST

Alternative vegetable crops—such as edamame, lima bean, and snap bean—are increasingly being grown for processing, and weeds are a major production problem, but there are few cost-effective tools to manage them. Dr. Marty Williams, research ecologist at the ARS Global Change and Photosynthesis Research Unit in Urbana, IL, and his colleagues studied the role of early-terminated cereal rye cover crop on weed suppression and vegetable crop yield. The system selectively enhanced weed control in edamame and was comparable to hand weeding. A new, economically viable solution to weed management now exists that lessens the reliance on herbicides for edamame. The expanding market in the United States for alternative vegetable crops, like edamame, supports the development of a domestic industry that is both competitive and sustainable.

PLAINS

Understanding if weeds are reproducing primarily through clones or seedling recruitment is particularly important for sustained management with biological control (biocontrol), which relies on specialized insects with selective feeding patterns to limit weed populations. Dr. Natalie West, research ecologist at the ARS Pest Management Research Unit in Sidney, MT, led studies to survey weed density, genetic diversity, and associated biocontrol agent abundance (*Aphthona* species flea beetles) in 100 leafy spurge populations across North Dakota, Montana, and Idaho. The survey provided insight into 1) how frequently seedlings contribute to population growth, and thus the density of leafy spurge infestations; and 2) whether leafy spurge density is related to the abundance of biocontrol agents and the balance between clonal and seedling recruitment into local populations. No evidence was found of frequent recruitment from seed at any of the sites. *Aphthona* spp. flea beetles were everywhere, but the association between the number of flea beetles and leafy spurge density was not consistent. Increased importance of seed production may be changing the most effective targets for biocontrol after decades of *Aphthona* pressure on leafy spurge invasions. Further testing is needed to ensure biocontrol management is sufficient for long-term sustainable control.

PACIFIC WEST

Restoring invaded and degraded rangelands is central to recovering the health and function of these regions throughout the western United States. Federal land managers and livestock producers have found that restoration of these systems is very difficult because native plants rarely establish from seeds. Dr. Roger Sheley, research ecologist at the ARS Range and Meadow Forage and Management Research Unit in Burns, OR, is leading research on a novel restoration system that includes using buds collected from native plant crowns and stored for planned restoration efforts. Their findings suggest that buds of bluebunch wheatgrass and Sandberg's bluegrass can be harvested mechanically and stored at about 4.4 degrees C. Bud longevity is associated with the amount of material that supports and surrounds the group of buds – the greater the amount of supporting material, the longer the stored bud remains viable. This is critically important to developing the new restoration system because crowns must be easily collectible and storable to be useful to managers.

SOUTHEAST

Spliceostatin C (spC), one of the bioactive components produced by the soil bacterium *Burkholderia rinojensis*, has displayed high phytotoxic activity at low doses against several weeds. However, the precise mechanism of action of spC is yet to be elucidated. Dr. Joanna Bajsa-Hirschel, a research plant physiologist at the ARS Natural Products Utilization Research Unit in Oxford, MS, is leading a team in studies analyzing the genomic sequences for 13 spC susceptible and resistant weeds and has found genetic mutations that could explain the range of toxic effects of spC. These findings are providing important information for further investigation into the possibility of generating spC-resistant crops through genetic engineering and breeding and developing spC as a bioherbicide, specifically targeting herbicide-resistant weeds.

OFFICE OF NATIONAL PROGRAMS – WEED SCIENCE NEWS

Collaboration, the backbone of research at ARS, helps to strengthen the efforts of scientists, broaden the reach to a wider range of stakeholders, and find solutions more quickly to the most pressing and challenging problems in agriculture. This theme underscores a symposium being organized by Steve Young, ARS national program leader, and Jim Kells, professor of weed science at Michigan State University, entitled, “WSSA research priorities survey results: 13 federal agency-perspectives and -funding opportunities”, which will take place at the annual meeting of the Weed Science Society of America on February 1 in Arlington, Virginia.

Along with ARS, 13 other Federal Agencies will be represented and include Animal and Plant Health Inspection Service (APHIS), National Institute of Food and Agriculture (NIFA), USDA Office of Pest Management Policy (OPMP), Natural Resources Conservation Service (NRCS), US Forest Service (USFS), Bureau of Land Management (BLM), US Geological Survey (USGS), National Park Service (NPS), US Fish and Wildlife Service (USFWS), Department of Defense (DOD), Army Corps of Engineers (ACOE), National Aeronautics and Space Administration (NASA), and National Science Foundation (NSF). These agencies support weed science research or invasive plant management, or both, through grant funding, technical assistance, and scientific studies. They represent a diversity of stakeholders who may be separated geographically yet have a common focus on weeds and invasive plants in crop, terrestrial, and aquatic systems.

With a panel of thought leaders from federal agencies and engagement from participants at the symposium, ideas will emerge on how best to use information from a recent WSSA-member survey in the development of a national roadmap for weed science. Young and Kells believe the symposium will provide an opportunity for a productive dialogue among federal agency leaders and WSSA members. By focusing on research needs, program support, and national initiatives in weed science, new relationships will be developed, and current ones will be strengthened.

RESEARCH SPOTLIGHT: DR. DAVID HORVATH

WSN sat down with Dave to discuss his research on how plants communicate in just about every form except audibly, but that might not be too far away. He also talks about those he has worked with and gives advice to those just starting their careers in science, as well as his favorite weed species. Dave is a research plant physiologist at the ARS Sunflower and Plant Biology Research Unit in Fargo, ND.

WSN: Hi Dave, how are you? Any snow yet?

Dave: Quite a bit! We got about 8 inches of extremely wet snow early last week followed by another 8 inches or so of slightly fluffier stuff on Thursday and Friday. Getting about an inch more of really fluffy stuff right now with temps heading into the -29 degrees C range by the weekend.

WSN: I assume that is good news with the ongoing drought, especially in the western part of the US. By the way, thanks again for taking time out of your day to talk about your research for the WSN. Perhaps you could share a little bit of your background to get started.

Dave: Sure, I started out way back in the early 80s at Purdue working with Jeff Bennetzen on abiotic stress in corn. He helped me get into the Lab of Mike Thomashow for my PhD (then at WA state before I moved with him to MI state). I was part of the team that cloned the first cold-induced genes in plants. I then did a post-doc with Dr. Lynn Dahleen with the USDA-ARS in Fargo and was in the right place and at the right time to land a permeant position with the Weeds Unit back in 1995. I was initially charged with investigating abiotic stress responses in leafy spurge, and rapidly started building tools to study leafy spurge at the molecular level and soon cloned a few cold-regulated genes from spurge. However, it became clear that in order to really control leafy spurge, we were going to have to understand how it produced, maintained and controlled the growth of the underground buds that allowed it to survive and thrive in the relatively harsh climates of the Northern Great Plains. This led to developing lots of molecular tools to make transcriptomics studies possible such as expression sequence tag (EST) database and microarrays. This allowed us to identify a DORMANCY ASSOCIATED MADS-BOX gene that is a critical component of dormancy control, not only in leafy spurge but in many perennial dicots. However, funding for leafy spurge research was hard to get, so we redirected ourselves to studying the response of corn to weeds (and potential cover-crops such as canola and camelina) and the mechanisms controlling cold acclimation and de-acclimation in canola and camelina to in hopes of creating a dual cropping system for the Northern Great Plains.

WSN: That is quite the effort in tackling one of the most challenging invasive plants. It still has a strangle-hold in some areas of the Northern Great Plains but understanding the basics of how it has been so successful is really key to developing sustainable management tactics. Shifting into crops, what does the molecular type of research that you do lead to in terms of improving our management of weeds?

Dave: Great question! One of our recent endeavors has been to understand how crops sense and respond to weeds. We have learned that weeds can reduce crop yields by inducing changes in their physiology and development that appear to have little or nothing to do with direct competition for resources. It appears that once weeds are detected by the crops, it sets off a chain reaction that results in the crop reducing their growth in anticipation of reduced resources – long before those resources are actually limiting – and is maintained even if the resources never become limiting. This is why growers can never fully mitigate weed presence by providing excess resources. If we can block crops from detecting and/or responding to weeds, we should be able to mitigate the yield losses caused by this response, and thus allow growers to gain full yield potential from their inputs even if weeds are present. Additionally, we should be able to better utilize cover crops or dual cropping systems to suppress weeds without the concomitant yield losses that are often observed in such systems. Finally, even though most growers are unlikely to let weeds grow unimpeded in their fields, even if they are not reducing the yields, it should help increase the critical period or window of opportunity for when weeds can be controlled.

WSN: So, you're saying that crops can effectively ignore weeds, just like two siblings competing for the last piece of cake? The younger one pays no attention to the older one and is able to consume every delicious morsel. If this isn't quite right, can you sum it up for everyone?

Dave: Partially correct. Yes, it will be able to get more of the nutrients than the weed since the weed (just like an unmodified crop) would likely be reducing its growth and development in anticipation of resource limitations. But the weed will undoubtedly still take up some resources. However, in most well managed agroecosystems there is generally plenty to go around, and the reduction in growth and development isn't as critical for survival as it would be in the wild. To summarize, making the crops blind to weeds will certainly allow them to grow to the fullest potential with the resources that are available without yield losses triggered by weeds that might be present.

WSN: Got it. Aside from sibling rivalry, do you foresee this "blindness" trait in crops working against all weeds?

Dave: I would suspect it should be a general response to at least most weeds. We have observed common responses activated by multiple different weeds under both field and greenhouse conditions. This suggests that there are features of the response to weeds that are rather general in nature. However, it would be quite surprising if there were not also species-specific interactions that exist. Allelochemical production (and/or susceptibility to such chemicals or even their production by the crop), for example, could be active in one crop-weed interaction, but be different or non-existent in another crop-weed interaction. We know from several studies that plants are very adept at determining not only that they have neighbors, but who those neighbors are, and will respond differently to different neighbors (be they weeds, other cultivars of their own species, or even siblings). Thus, some aspects of crop-weed interactions are likely to be general, and some more species specific.

WSN: This is all very interesting, and it seems like there is a lot yet to be learned, but let's discuss some of the parallels. One of the obvious ones is insects – how do you view the topic of communicating among plant species as similar or different to how, say, beetles or ants talk to each other? What are scientists in the field of entomology finding, if you know or can speculate?

Dave: Another good question. It is well known that insects use volatile chemicals to communicate with each other and to find mates and prey. Likewise, we know that plants can also communicate with each other by volatile compounds. For example, plants being attacked by insects will produce volatiles that signal potential imminent attack to both un-attacked portions of themselves as well as to their neighbors. This allows those un-attacked leaves and plants to begin producing defensive chemicals and increasing the strength of their cell walls. Although we have not yet found many volatile signals playing a role in crop-weed interactions, it would be surprising if they are not only present, but common.

Another signal insect use in their interactions are light signals. Insects can detect light signals in both the visual and infra-red and ultraviolet ranges. Likewise, it has long been known that plants can detect their neighbors through increases in the ratio of far-red to red light through the protein phytochrome. Far-red light is reflected by chlorophyll and red light is absorbed by it. Thus, when plants are close to each other, they can detect these changes in light quality and alter their development and growth in anticipation of future competition for light. Additionally, recent work out of the lab of Clarence Swanton have demonstrated that high levels of far-red light can induce oxidative stress that reduces the ability of plants to photosynthesize. Additionally, plants can "see" their neighbors by detecting changes in the levels of ultrablue light as well through proteins called cryptochromes in much the same way they detect neighbors by changes in red:far to red light ratios.

Insects will also interact and communicate with each other by touch. Likewise, plants can tell when they are touching other plants. There have been studies such as a very interesting one by Mieke de Wit et al. in PNAS in 2012 that demonstrated that leaf to leaf contact in the model plant Arabidopsis causes the leaves to orient upwards (a response called hyponasty), and that this response precedes the light responses. Thus, plants can detect their neighbors by virtually all of the same senses used by insects- and mammals for that matter.

WSN: Okay. You've given a pretty extensive lesson in plant physiology/biochemistry minus the equations and chemical structures. No need to go there, as I am sure you'd need a college classroom, which is a bit beyond this interview. All joking aside, this is really fascinating research, which I imagine requires a team of scientists. Who are some that you work with and what is their area of expertise?

Dave: I am of course working with the other scientists in my Unit, Dr. James Anderson who has extensive experience in plant biochemistry, and Dr. Wun Chao who is an excellent molecular biologist. I am also working closely with Dr. Sharon Clay, a renowned agronomist at South Dakota State University, and Dr. Clarence Swanton who is a renowned weed scientist and agronomist at the University of Guelph in Canada. Indeed, a manuscript authored by all of the above that reviews these concepts in Trends in Plant Sciences was just accepted, so you can look for that in the near future if you want further reading and sources. In addition to these colleagues, there are many experts in plant-plant communications who I have discussed ideas with, such as Dr. Ronald Pierik from the Plant Ecophysiology, Institute of Environmental Biology, Utrecht University, The Netherlands, and the Swedish University of Agricultural Sciences, Department of Crop Production Ecology, Sweden; Dr. Fabrice Roux from the Université de Toulouse, INRA, CNRS, Castanet-Tolosan, France, and am collaborating with Dr. Diane Bassham at Iowa State University to test our hypothesis that TOR kinase is a central player in the growth responses of crops that were exposed to weeds. I have had a good bit of assistance with bioinformatics from the likes of Dr. Colleen Doherty at North Carolina State University, Dr. Natalie Clark at the Broad Institute, and Dr. Changhui Yan at North Dakota State University. Thanks to funding from a post doc grant from ARS, I also have the assistance of Dr.

Barbara Dobrin who is looking into using AI technologies help mine the mountains of RNAseq data we have generated to help us identify additional signaling processes involved in crop-weed interactions.

WSN: What a network! I would guess that these connections didn't just come about by cold calls, right? Can you share a little bit on how these have developed and a few pointers, so that junior faculty or those still in graduate school can learn the art?

Dave: Actually, some of them did come about by cold calls. For example, I was looking for someone to help me test my hypotheses surrounding the TOR kinase complex, and I looked in the literature and found Dr. Bassham's work. I then sent an email to see if she was interested in collaborating and initiated that work. Likewise, while writing the review paper I ran across a paper by Dr. Roux on using genome-wide association studies to identify genetic loci associated with inter-species plant-plant interactions. I was fascinated by it because I was thinking about trying something similar and I had some questions about the study she had done. Thus, I sent her an email. The resulting conversations were both interesting and enlightening, and it seems likely that we will be organizing a workshop at the 2024 Plant and Animal Genome Conference. I met Ronald Pierik at an American Society of Plant Physiology (ASPB) meeting after he gave a plenary talk on plant-plant communications. That led to him giving us some assistance in interpreting some of our results on soybean-crop interactions from our first foray into RNAseq studies. Likewise, Dr. Clark gave a great presentation on network analysis at a different ASPB meeting, so I sent her an email to seek her assistance with another complex data set I was struggling with. I met both Drs. Clay and Swanton at weed science meetings as they were doing various crop-weed interaction studies that I was interested in applying transcriptomics techniques on to gain additional insights. Also, I had read Dr. Swanton's work on corn-weed interactions that convinced me that crop-weed interactions were more dependent on signaling of developmental shifts than direct competition for resources. Dr. Doherty came out of the same Thomashow lab as me and I had been following her work in bioinformatics for years. We also served on the membership committee for ASPB together. Thus, I think one theme running through all of this is that scientific societies and the connections they encourage are seriously important for any scientist at any stage of their career.

WSN: Thanks for sharing this. I am sure many reluctant graduate students will not feel quite as timid in reaching out to a more senior and perhaps well-published scientist. It just makes for better footing when we "stand on the shoulders of giants." One last thing before I let you go – what is your favorite weed species and why?

Dave: I'll add a bit to that: People love it when others are interested in their work. Never be afraid to contact other scientists and ask them about their work. You will undoubtedly learn a lot and make a friend, and connections and collaborations are the single most important thing a scientist can do to further their career.

In answer to your question though, I have to say leafy spurge is pretty cool, and there is still a lot that that weed can teach us about invasiveness, plant development, and traits that are needed to not only establish, but thrive in harsh northern environments. We did some early investigations into the gene expression differences between leafy spurge in North Dakota as compared to leafy spurge in its native range in the Ukraine, that need to be redone using newer RNAseq techniques. Additionally, using genome wide association studies with invaded and native range populations, it should be possible to identify selected genes and loci upon introduction to North America. Incidentally, a genome sequence of leafy spurge should be available soon, which would greatly help future studies.

That said, I think that alligatorweed is a fascinating species in that it is an aquatic invasive weed that also seems to be able to shift growth and development to land. It has recently developed the ability to extend its range from warm temperate and tropical environments to now being able to grow as far north as Maryland, northern California and northern provenances of China. From work with a collaborator in China, we know that this range expansion is due to genetic changes and is not simply the result of global warming. Understanding the genetic changes that allowed this range expansion could provide us with targets to increase the expansion of crop species such as winter canola that we are trying to adapt to the harsher winters here in the Dakotas.

WSN: Those are two very well-known and challenging invasive plants with plenty more for us to discover and learn. Perhaps even utilizing their genetics to improve some of our crops – that is a topic for another time. Thanks for spending a little of your day sharing your research at ARS. Any final thoughts or parting words of wisdom?

Dave: Just that it is an exciting time in weed science with the fantastic tools and advances in genomics and marker associations, bioinformatics and transcriptomics, and AI technologies for pattern finding in the two previously mentioned fields as well as phenotypic analyses for weed identification and weed responses to their environment that are becoming mainstream in weed science and allowing us to answer some of the fundamental questions about the evolution of invasiveness, adaptation to stress – including herbicides – and interaction with crops that have previously alluded weed scientists. I am looking forward to the next 10-15 years as these tools are used to answer key questions and provide fascinating insights. It has been a fun interview. Thanks for inviting me.

WSN: Absolutely! Looking forward to seeing your research in upcoming issues of the newsletter. Thanks again!

ARS Weed Science Events, Positions, and Papers

ARS Meetings/Conferences/Webinars/Symposia

2023 WSSA Annual Conference – Symposia (website: https://wssa.net/current-annual-meeting/)

- The good, the bad, and the ugly – the current state of cover crops and weed management – Erin Haramoto, University of Kentucky and Steve Young, USDA-ARS (organizers)
- Crop weed management in a rising CO_2 and warming world – Marty Williams, USDA-ARS (organizer)
- WSSA research priorities survey results: 13 federal agency-perspectives and -funding opportunities – Jim Kells, Michigan State University and Steve Young, USDA-ARS (organizers)

2022 WSSA-ARS Weed Science Webinar Series – All 10 webinars from the series were recorded and are now available free for viewing. Website: https://www.ars.usda.gov/crop-production-and-protection/crop-protection-and-quarantine/docs/weed-science-webinar-series/

ARS Weed Science Positions – check USAJobs.gov for more information or contact Steve Young.

- Invasive Plant Scientist/Ecologist – Ft. Lauderdale, FL
- Weed Geneticist – Pullman, WA

Select ARS Papers – recently published by researchers in weed science

- Amy DaSilva, Angelica M. Reddy, **Paul D. Pratt**, Marielle S. Hansel Friedman, **Brenda J. Grewell**, Nathan E. Harms, Ximena Cibils-Stewart, Guillermo Cabrera Walsh, Ana Faltlhauser, M. Lourdes Chamorro (2022) "Biology of Immature Stages and Host Range Characteristics of *Sudauleutes bosqi* (Coleoptera: Curculionidae), a Candidate Biological Control Agent of Exotic *Ludwigia* spp. in the USA," Florida Entomologist, 105(3), 243-249
- **Patrick J. Moran**, Rosemarie De Clerck-Floate, Martin P. Hill, S. Raghu, Quentin Paynter, John A. Goolsby, (2023) Chapter 6 - Mass-production of arthropods for biological control of weeds: a global perspective, Editor(s): Juan A. Morales-Ramos, M. Guadalupe Rojas, David I. Shapiro-Ilan, Mass Production of Beneficial Organisms (Second Edition), Academic Press. Pages 157-194
- **Natalie M. West**, **John F. Gaskin**, Joseph Milan & Tatyana A. Rand (2022) High genetic diversity in the landscape suggests frequent seedling recruitment by *Euphorbia virgata* Waldst. & Kit. (leafy spurge) in the northern U.S.A. *Biol Invasions* (2022). https://doi.org/10.1007/s10530-022-02954-9

- Eliza I. Clark, Amanda R. Stahlke, **John F. Gaskin**, Dan W. Bean, Paul A. Hohenlohe, Ruth A. Hufbauer, Ellyn V. Bitume (2023) Fitness and host use remain stable in a biological control agent after many years of hybridization, Biological Control, Volume 177, 2023, 105102
- Lowry, C., Matlaga, D., **West, Natalie**, **Williams, Martin**, & Davis, A. (2022). Estimating local eradication costs for invasive Miscanthus populations throughout the eastern and midwestern United States. *Invasive Plant Science and Management, 15*(3), 115-121.
- McGranahan, D.A., **Wonkka, Carissa L.** (2022) Fuel Properties of Effective Greenstrips in Simulated Cheatgrass Fires. *Environmental Management* 70, 319–328 (2022).
- **Joanna Bajsa-Hirschel**, **Pan Zhiqiang**, Pandey Pankaj, Asolkar Ratnakar N., Chittiboyina Amar G., Boddy Louis, Machingura Marylou C., Duke Stephen O. (2023) Spliceostatin C, a component of a microbial bioherbicide, is a potent phytotoxin that inhibits the spliceosome. Frontiers in Plant Science 13
- Dobbs, A., Ginn, D., Skovsen, S., Bagavathiannan, M., **Mirsky, Steven B.**, Reberg-Horton, C., & Leon, R. (2022). New directions in weed management and research using 3D imaging. Weed Science, 70(6), 641-647.
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- Feng Gao, Jyoti Jennewein, W. Dean Hively, Alexander Soroka, Alison Thieme, Dawn Bradley, Jason Keppler, **Steven Mirsky**, Uvirkaa Akumaga (2023) Near real-time detection of winter cover crop termination using harmonized Landsat and Sentinel-2 (HLS) to support ecosystem assessment. Science of Remote Sensing, Volume 7, 100073
- **Gregory S. Wheeler**, Carey Minteer, Eric Rohrig, Sedonia Steininger, Rebecca Nestle, Dale Halbritter, Jorge Leidi, **Min Rayamajhi**, Emily Le Falchier (2022) Release and Persistence of the Brazilian Peppertree Biological Control Agent Pseudophilothrips ichini (Thysanoptera: Phlaeothripidae) in Florida. Florida Entomologist, 105(3), 225-230
- Christopher A. Landau, Aaron G. Hager, **Martin M. Williams** (2022) Deteriorating weed control and variable weather portends greater soybean yield losses in the future. Science of The Total Environment, Volume 830, 154764
- **Chad S. Boyd**, Rory C. O'Connor, Juliana Ranches, David W. Bohnert, Jon D. Bates, Dustin D. Johnson, Kirk W. Davies, Todd Parker, Kevin E. Doherty (2022) Using Virtual Fencing to Create Fuel Breaks in the Sagebrush Steppe. Rangeland Ecology & Management. ISSN 1550-7424
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- **David P. Horvath**, Sharon A. Clay, Clarence J. Swanton, James V. Anderson, Wun S. Chao (2023) Weed-induced crop yield loss: a new paradigm and new challenges. Trends in Plant Science. ISSN 1360-1385
- **Stephen L. Young** and Erik P. Hamerlynck (2023) Patterning ecological restoration after weeds. Restoration Ecology e13841.