# 14th ANNUAL LRES-PSPP STUDENT RESEARCH SYMPOSIUM

April 18, 2024
Montana State University
Bozeman, Montana

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**LRES Graduate Student Organization**

*Scan the QR code to check out our website and see the full digital program!*

# Schedule of Events

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|---|---|
| **2:15** PM **– 3:00** PM | **Poster Check-In** |
| **3:00** PM **– 3:15** PM | **Opening remarks**<br>• Dr. Sreekala Bajwa, Dean, College of Agriculture<br>• Dr. Robert Peterson, Department Head, Land Resources and Environmental Sciences<br>• Dr. Mike Giroux, Department Head, Plant Sciences and Plant Pathology |
| **3:15** PM **– 4:30** PM | **Oral presentations session 1** |
| **4:30** PM **– 6:00** PM | **Poster session and social hour**<br>• 21 posters<br>• Heavy appetizers |
| **6:00** PM **– 6:30** PM | **Keynote presentation: Dr. Liz Carlisle**<br>*Healing Grounds: Climate, Justice, and the Deep Roots of Regenerative Farming* |
| **6:45** PM **– 7:45** PM | **Oral presentations session 2** |
| **7:45** PM **– 8:00** PM | **Prize presentation and closing remarks** |

# Keynote Presentation

**Liz Carlisle** is an Associate Professor in the Environmental Studies Program at UC Santa Barbara, where she teaches courses on food and farming. Born and raised in Montana, she got hooked on agriculture while working as an aide to organic farmer and U.S. Senator Jon Tester, which led to a decade of research and writing collaborations with farmers in her home state. She has written three books about regenerative farming and agroecology: *Lentil Underground* (2015), *Grain by Grain* (2019, with co-author Bob Quinn), and most recently, *Healing Grounds: Climate, Justice, and the Deep Roots of Regenerative Farming* (2022). She is also a frequent contributor to both academic journals and popular media outlets, focusing on food and farm policy, incentivizing soil health practices, and supporting new entry farmers. She holds a Ph.D. in Geography, from UC Berkeley, and a B.A. in Folklore and Mythology, from Harvard University. Prior to her career as a writer and academic, she spent several years touring rural America as a country singer.

You can learn more about Dr. Carlisle on her website at lizcarlisle.com.

# Symposium Information

**Abstracts:** Abstracts for all oral presentations and posters can be found on our website, lres-research-symposium.weebly.com, or at the end of this program.

**Participation:** This year's symposium features 21 posters and 12 oral presentations, showcasing research from 9 undergraduate and 22 graduate researchers.

**Judging and Awards:** Judges will be present during the oral and poster sessions. Prizes donated by LI-COR and AMS will be awarded to the top 3 poster and top 3 oral session presenters.

# 2024 LRES-PSPP Student Research Symposium Organizers and Volunteers

The 2024 LRES-PSPP Student Research Symposium was organized and funded by the LRES Graduate Student Organization and the department of Plant Sciences and Plant Pathology. More information on the LRES GSO can be found at landresources.montana.edu/gso.

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**Volunteers:** Chloe Hinson, Erika Consoli, Nagendra Singh

# Expanded Presentation Schedule

| Oral Presentations Session 1<br>3:15 – 4:30 PM | |
|---|---|
| 3:15-3:25 | *Influence of Crop Rotations and Soil Disturbance on Soil Carbon Sequestration in Dryland Cropping Systems in Montana*<br>**Samuel Koeshall**, LRES |
| 3:27-3:37 | *Impacts of herbicide, and macro- and micro-nutrients on ventenata and desired species composition in Montana rangelands*<br>**Lilly Sencenbaugh**, LRES |
| 3:39-3:49 | *Embarking on a Taxonomic Odyssey: A revision of the West Indian Belonuchus*<br>**Jordan Rainey**, PSPP |
| 3:51-4:01 | *Identification of cGAS-like receptors in honey bees (Apis mellifera)*<br>**Hunter Charles**, PSPP |
| 4:03-4:13 | *From Aquatics to Inquilines, our Evolving Understanding of Larval Chelonariidae*<br>**JP Kole**, PSPP |
| 4:15:4:25 | *Heat Stress Tolerance in Spring Wheat Induced by Brassinosteroid Hormone*<br>**Chloe Hinson**, PSPP |
| 4:27-4:37 | *Effects of cover crop interseeding on weed communities in organic carrot farming*<br>**Reilly Stack**, PSPP |
| **Oral Presentations Session 2<br>6:45 PM – 7:30 PM** | |
| 6:45-6:55 | *Altering Flowering Time in Wheat for Yield Stability Amidst a Changing Climate*<br>**Brandon Tillett**, PSPP |
| 6:57-7:07 | *Breeding Super Wheat*<br>**Caleb Hale**, PSPP |
| 7:09-7:19 | *Gene Expression Effects of Pea Seed Protein*<br>**Shreejana KC**, PSPP |
| 7:21-7:31 | *Assessing novel downy brome management tactics to improve rangeland sustainability*<br>**Erin Teichroew**, LRES |
| 7:33-7:43 | *Pyramiding Resistant Genes for Aphanomyces Root Rot Resistance in Peas*<br>**Jenish Simon**, PSPP |

# 10-Minute Oral Presentation Abstracts

*Abstracts are listed alphabetically by last name*
*u = undergraduate | g = graduate*

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## Hunter Charles [g]

*Identification of cGAS-like receptors in honey bees (Apis mellifera)*

P.I. Dr. Michelle Flenniken

Pattern recognition receptors (PRRs) that detect pathogen derived nucleic acids are important for antiviral defense. Viral infections contribute to honey bee (*Apis mellifera*) colony deaths, which have averaged 38% annually in the US since 2008. Double-stranded RNA (dsRNA) is a potent stimulator of antiviral defenses and is generated during virus replication, including the positive sense single-stranded RNA viruses that infect honey bees. Honey bee dsRNA-triggered antiviral defense mechanisms include sequence-specific RNA interference (RNAi) and a sequence-independent response, but the PRRs that mediate these responses are not well characterized. In vertebrates, the cyclic GMP-AMP synthase (cGAS)-stimulator of interferon genes (STING) pathway is stimulated in a sequence-independent manner by cytosolic double-stranded DNA, resulting in antiviral responses. Recent studies show that some invertebrate cGAS homologs, termed cGAS-like receptors (cGLRs), bind dsRNA to initiate antiviral responses. To investigate if a cGLR-STING pathway contributes to honey bee sequence-independent antiviral responses, we identified three putative honey bee cGLRs and one STING ortholog. Expression of cGLRs and STING was higher in virus-injected bees compared to mock-infected controls. Ongoing studies aim to understand the role of the cGLR-STING pathway in honey bee antiviral defense and may inform the development of strategies that limit virus-associated honey bee colony losses.

## Caleb Hale [g]

*Breeding Super Wheat*

P.I. Dr. Mike Giroux

Traditional plant breeding generally involves the lengthy strategy of making crosses between good parent varieties, generating large populations from these crosses, and collecting years of data on these populations to figure out which individual lines might be even better than the original parent varieties. Modern technology has allowed plant geneticists to discover which specific genes are allowing plant varieties to improve over time, and which alleles (versions of these genes) are best. In addition to searching for better lines in huge populations, plant breeders are now able to take a good variety and make it even better by crossing in beneficial alleles and creating a new version of the variety that is improved in specific ways. Using these methods, we have taken an elite Montana durum variety, MT Raska, and crossed in three different alleles to make a “Super Raska” that is higher yielding, slightly taller, and more resistant to heavy metal accumulation.

## Chloe Hinson [g]

*Heat Stress Tolerance in Spring Wheat Induced by Brassinosteroid Hormone*

P.I. Dr. Jennifer Lachowiec

As the world experiences increasing climate extremes, stress tolerance of crop plants is essential for sufficient food production. Brassinosteroid (BR) hormones are short distance plant growth promoters that have significant crosstalk with other hormones to orchestrate the balance between plant development and stress response. Exogenous BR applications increase the tolerance of many important crops to a variety of stressors. For wheat, soaking germinating seeds in BR partially rescues growth characteristics after the plant is exposed to heat while the wheat head is developing during the booting stage. Under heat stress, reactive oxygen species such as hydrogen peroxide ($H_2O_2$) are produced – not only because of cell damage but also to act as signal molecules within and between cells. For several dicot plants, $H_2O_2$ generation and proliferation is essential for BR-meditated heat stress tolerance since inhibition of $H_2O_2$ synthesis abolishes BR protective effects. However, evidence suggests that the BR-$H_2O_2$ interaction contributing to stress tolerance may be acting differently in monocot plants. Further, little is known about why soaking seeds in BR contributes to trait improvements during the reproductive phase. Investigating the mechanism in monocots that $H_2O_2$ utilizes to coordinate hormonal stress responses can unravel the interplay of reactive oxygen species as stress mediators.

## Shreejana KC [g]

*Gene Expression Effects of Pea Seed Protein*

P.I. Dr. Kevin McPhee

Peas are an excellent source of plant-based protein. Understanding gene expression patterns associated with pea protein accumulation is vital to successful crop breeding and plant protein use. Factors impacting breeding and use include gene regulation, developmental biology, environmental factors, and agricultural practices. This study was intended to evaluate changes in gene expression due to the environment. The experimental design included 350 accessions planted in an RCBD design with two replications. Fresh pods were collected in the R3 stage with visible flat pods or the R4 stage when green seeds fill the pod cavity and stored at -80°C until RNA extraction. 300mg of seed tissue was ground using a mechanical homogenizer followed by lysis. RNA separation, purification, and RNA quality assessment was done using Nanodrop and Qubit. The extracted sample was sent for RNA sequencing. The received FastQC data was then cleaned and trimmed using Trimmomatic and aligned using STAR. The BAM file generated after alignment will be subjected for further differential analysis using R package DESeq2 where transcriptomic analysis will be performed to generate heat maps and volcano maps. Genes upregulated and downregulated for pea protein accumulation will be identified.

## Samuel Koeshall [g]

*Influence of Crop Rotations and Soil Disturbance on Soil Carbon Sequestration in Dryland Cropping Systems in Montana*

P.I. Dr. Perry Miller

Various types of dryland cropping systems are found in Montana, differing via factors such as crop species and levels of soil disturbance utilized in fields. Farmers now have the opportunity to create an additional revenue stream via carbon markets that pay based on various production

practices used, such as no-till management or seeding cover crops, for example. In some domestic carbon markets, soil organic carbon (SOC) may be worth as much as $130 per ton. However, the net gain or loss in SOC due to implementing a certain cropping system is largely unknown. Furthermore, seeding type and stubble management vary across and within dryland cropping rotations used in Montana. The variation in crop rotations, seeding type, and stubble management used in Montana may all influence the rate of SOC accrual, which would affect annual carbon payments and other agro-economic parameters such as yield or net returns. The goal of this study is to understand how unique dryland cropping systems vary in agro-economic performance and SOC accrual as influenced by eight unique crop rotations commonly found in Montana and two forms of soil disturbance as caused by differing seeding methods and stubble management.

## JP Kole [g]

*From Aquatics to Inquilines, our Evolving Understanding of Larval Chelonariidae*

P.I. Dr. Michael Ivie

The Chelonariidae are a family of compact beetles in the superfamily Byrrhoidea. More than 200 species of chelonariids have been described; however, very few larvae are known, and even fewer are associated with adults. The larvae of Chelonariidea are easily recognized and morphologically unusual, bearing long setae on characteristic lateral and dorsal protuberances, and in life being covered by a sticky exudate. Many early writers considered them to be aquatic, a notion which has since been largely discredited. More recent authors have considered them to be inquilines of ant or termite nests. This contention is difficult to support as few larvae are known at all, with their habits being more mysterious still. Examinations of the West Indian Chelonariidae have allowed us to associate the adults and larvae of three species, with an additional two species of larvae identified which cannot be associated with conspecific adults. Several morphological characters have proven useful in distinguishing between the larvae of West Indian Chelonariidae, indeed the larvae are often more easily distinguished than the adults. Significant further work is required for the remaining species, especially concerning Pseudochelonarium Pic, 1916 and Brounia Sharp, 1878 as no larvae are known of these genera.

## Jordan Rainey [g]

*Embarking on a Taxonomic Odyssey: A revision of the West Indian Belonuchus*

P.I. Dr. Michael Ivie

Staphylinidae (the rove beetles) are a hyper-diverse family of beetles consisting of over 67,000 species. They are the most species rich family in the Animalia, being found in a wide range of habitats, and are even present in the Sub-Antarctic region. My MS research focuses on producing a taxonomic revision of the staphylinid genus *Belonuchus* in the West Indies to address a knowledge gap in our understanding of the genus. The genus now contains 17 species found in the West Indian biogeographical area, seven of which are described as new species. Historic taxonomic mistakes are corrected, and redescriptions and rediagnoses are provided for previously described species. All species are included in a taxonomic identification key, diagnostic characters are illustrated, distribution maps are made for each species, and updates on the nomenclature of the group are provided. In this talk I will summarize the findings and the overall purpose of this revision.

## Lilly Sencenbaugh [g]

*Impacts of herbicide, and macro- and micro-nutrients on ventenata and desired species composition in Montana rangelands*

P.I. Dr. Lisa Rew

Montana rangelands are being invaded by non-native annual grass *Ventenata dubia*, and effective management strategies are needed. *Ventenata dubia* is a species with unreliable forage quality that has become a problem for Montana producers who need to produce high quantities of quality forage. Further, in rangelands it invades and forms dense monocultures that negatively impact native species richness. This project sought to quantify *Ventenata* and desired grasses' responses to integrated management. We quantified *Ventenata* control and response of desired forage following herbicide treatments (flufenacet+metribuzin, indaziflam, indaziflam+imazapic) and macro- and micro-nutrient fertilizers (NPK, Nutrafix™) at three sites across Montana. While there is some evidence of improved forage abundance following indaziflam treatments in *Ventenata* invaded fields, the addition of fertilizer treatments may further improve the quantity of desired forage. We found our herbicide treatments to be effective at reducing *Ventenata* cover, with no effect on desired forage or native species richness. We did not find any differences in forage abundance following the fertilizer treatments, which may require more years for discernable effects. Ultimately, this research highlights the importance of monitoring desired forage response along with the target weed.

## Jenish Simon [g]

*Pyramiding Resistant Genes for Aphanomyces Root Rot Resistance in Peas*

P.I. Dr. Kevin McPhee

Pea is a crucial legume crop with respect to protein, nitrogen fixation, and crop rotation practices making it important for both human and animal consumption. Pea cultivation faces challenges from both biotic and abiotic stress. Soil-borne root rot pathogens lead to significant yield losses, up to 70%. Aphanomyces root rot (caused by *Aphanomyces euteiches*) stands out as one of the most destructive oomycete pathogens capable of attacking pea plants at any stage of development. This research aims to develop pyramid resistance genes from different pea genotypes and germplasm with greater resistance to Aphanomyces root rot. PI 652444, PI 652445, and PI 652446 lines have low disease incidence (mean 0.1, 0.6, 0, respectively), and MTP190144 and MTP191417 have high disease incidence (mean 2.3, 2.8, respectively). The first approach is to characterize reportedly resistant germplasm for reaction to Aphanomyces through rigorous pure culture screening. Subsequently, molecular markers will be generated to facilitate the introgression of Aphanomyces resistance traits into adapted genetic backgrounds as germplasm or cultivars suitable for cultivation in Montana.

## Reilly Stack [u]

*Effects of cover crop interseeding on weed communities in organic carrot farming*

P.I. Dr. Fabian Menalled

Cover crops are a promising weed management tool with a variety of ecological benefits, but there is a gap of knowledge regarding the effects of interseeded cover crops on weed communities, as well as the specific cover crop varieties most suitable for organic systems in Montana. A deeper understanding of these effects will allow organic producers to implement

integrated management practices more effectively. This research investigates the impacts of interseeded cover crops on weed communities in organically grown carrot (*Daucus carota*). At MSU Towne's Harvest Garden, we are evaluating changes in weed abundance and species composition across interseeded annual ryegrass (*Lolium multiflorum*), berseem clover (*Trifolium alexandrinum*), summer alfalfa (*Medicago sativa*), and a control treatment without any cover crop. The experiment follows a randomized block design with four replications in 46' by 5' plots, with cover crops established on July 6, 2023. On August 9, 2023, we collected weed and cover crop biomass, and performed counts by species using 50 cm by 20 cm quadrats. Counts and biomass data has been recorded, and analyses will include diversity indices, species richness, and community composition. Preliminary observations suggest that plots containing cover crops have a significant reduction in weed density compared to the control. It also appears that certain weed species, including common henbit (*Lamium amplexicaule*), have highly variable densities across treatments. Results are anticipated to be completed by Fall 2024.

## Erin Teichroew [g]

*Assessing novel downy brome management tactics to improve rangeland sustainability*

P.I. Dr. Lisa Rew

Sustainable rangelands can support environmental, social, and economic goals of ranchers and resource managers in the Intermountain West. A key challenge in maintaining sustainable rangelands is managing non-native species. Effective management tools for cheatgrass (*Bromus tectorum L.*) are desired by many managers and producers. Currently most rely on herbicides for management but effective alternatives are needed. We tested two novel cheatgrass management methods, a biofumigant and a soil amendment, and compared them to herbicide and non-management options. Five trials were established at three locations in southwestern Montana. Seven treatments were applied: a non-treated control, two levels of biofumigant (mustard seed meal), three levels of soil amendment (Nutrafix), and one level of herbicide (indaziflam). We analyzed the impacts of the treatments on the biomass of cheatgrass and perennial grasses over three years. We found cheatgrass biomass was reduced the first year after application by most treatments but returned to pre-treatment levels three years post application. Biomass of perennial grasses increased in the indaziflam plots. These results indicate that our treatments may be effective for short term management of cheatgrass, but long-term control was not obtained and the desired increase in the native plant community was limited.

## Brandon Tillett [g]

*Altering Flowering Time in Wheat for Yield Stability Amidst a Changing Climate*

P.I. Dr. Mike Giroux

Climate change has extended the growing season in Montana by 12 days since 1950. Early July, the time of pollination for spring wheat, has been getting hotter, creating challenges for pollen integrity and yield stability. This study is focused on three different genes in spring wheat that impact the timing of floral development and pollination. There are three copies of each gene in spring wheat, creating nine opportunities to alter flowering time by a day or so. Utilizing the exciting CRISPR technology, lines are under development that vary for all nine of these genes in spring wheat, which will result in a large window of different flowering times. These lines will be tested around the state at the various experimental stations to determine the best timing of wheat floral development to maintain yields across the different regions of Montana.

# Poster Abstracts

*Abstracts are listed alphabetically by last name*
*u = undergraduate | g = graduate*

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## Laura Berrios-Ortiz [g]

*Facilitating transitions toward winter wheat sustainability: Ecological insights and management solutions*

P.I. Dr. Fabian Menalled

Winter wheat in the Northern Great Plains faces threats from pest complexes, including *Bromus tectorum* (cheatgrass) and Fusarium crown rot. Despite their combined impact, management strategies often overlook their interaction. Our study investigates how crop management affects these pests to provide ecologically based recommendations. We explore the combined effects of *B. tectorum* and *Fusarium pseudograminearum* with available primary plant nutrients and seeding rate on yield and grain protein content. The study was conducted across three test sites in Montana and using a split-plot design, we analyzed both responses using linear mixed model backward selection process and ANOVA type III tests with libraries lme4 and car in R. Results showed interactions across available nitrogen, available potassium, and *B. tectorum* abundance affecting grain protein content ($p = 0.04$). Furthermore, interactions across available phosphorus, available nitrogen, seeding rate, and *F. pseudograminearum* ($p = 0.03$), and interactions across available phosphorus, available nitrogen, seeding rate, and *B. tectorum* abundance ($p<0.001$) affected yield. Acknowledging these interactions enables informed decision-making for sustainable agriculture. We aim to understand the dynamics that drive ecological connections in order to provide environmentally sound recommendations for managing grassy weeds and pathogens in winter wheat.

## Tyler Boyd [g]

*The Wild West of Rangeland Soil Health*

P.I. Dr. Anthony Hartshorn

The Piikani Lodge Health Institute-led "Grazing for soil health" project is baselining characteristics for ~30 Blackfeet Nation ranches. Here, we report preliminary results for 20 catenas (~200 soil profiles), including volumetric soil organic carbon (SOCv) in English tons per acre to one-foot depth (multiplied by 2.24 to obtain Mg SOC $ha^{-1}$ $[30\ cm]^{-1}$ or 0.224 to obtain kg SOC $m^{-2}$ $[30\ cm]^{-1}$). Across all catenas, we typically dug and sampled 4 pits per landscape position, with the average SOCv estimated as the sum of the products of horizon-specific estimates of the rock-free fraction, SOC on a mass basis (estimated from SOM), and bulk density. We found a ~10X range in SOCv, from 7 to 140 t SOC/ac-ft, even as our CVs ranged between 4 and 76. Prior work across the Great Plains (Aguilar et al. 1988) had shown that rangeland SOCv generally increased from ~33 to ~85 t SOC/ac-ft from summits to toeslope positions. For 8 of our catenas, however, we found that summit positions contained more SOCv than others. While our results confirm the value of a catena approach for ranch baselines, they also quantify variability that could hamper linking management practices to shifts in soil health.

## Akamjot Brar [g]

*Fall application of soil residual herbicides can reduce broadleaf weed abundance in chickpeas*

P.I. Dr. Lovreet Shergill

Pulses, including chickpeas, offer expanded market opportunities, but their slow germination and early growth make early stage weed control crucial for successful establishment. Fall application of soil-active residual herbicides can aid in early-season weed suppression and improve the establishment of spring-planted chickpeas. Field experiments were conducted with randomized complete block design with 4 reps and 14 treatments at two sites, Southern Agriculture Research Center, Huntley, and Western Agriculture Research Center, Corvallis, during 2022 and 2023 to evaluate crop safety and broadleaf weed control by fall-applied soil active herbicides followed by a POST application in chickpeas. Pyroxasulfone at 131 g/ha ae+ flumioxazin at 60.6 g/ha ae, dimethamid at 950 g/ha ae + pendimethalin at 1.68 kg/ha ae, and metribuzin at 420 g/ha ae provided 90-99% broadleaf weed control at both sites Kochia, Common Lambsqaurters and Redroot pigweed. A follow-up POST application of pyridate (700 g/ha ae) helped ensure season-long control by eliminating weeds that escaped PRE. There was no visual injury of any herbicide and yield reductions in chickpeas; a 90-100% increase in yield compared to untreated control was observed with best treatments. These herbicide programs can be integrated with other weed management tactics in pulse crops for effective weed control.

## Mia DeGarmo [u]

*Longitudinal Bee Sample Composition Comparison of Study Traps*

P.I. Dr. Michael Ivie

The purpose of this study is to compare the morphospecies composition of samples of bees taken from 30th May through 15th September 2023 between bee bowls and blue vane traps at Greer Gulch in Lewis and Clark Caverns State Park. This comparison is to determine differences in trap catch and changes in species composition over the course of the season. Through comparing the composition of these traps, it will be determined what, if any, change occurred throughout the season. To successfully achieve the research purpose, specimens collected in the study traps at Greer Gulch between the collection period must be curated and sorted into morphospecies, and the data, with identifications, must be entered into the WBMP database. These sample data will be compared for completeness for each trap type and trap period to a random bootstrap model, thus determining if a single sample can be representative of the total pool of species present in all samples from a single season collection period. The application of the reported findings from this study and the implications of the collection design will then determine the best ongoing WBMP sample structure to continue documentation efforts of wild bees in the state.

## Devanshi Desai [g]

*In-Vitro Evaluation of Sorgoleone for Monocot Weed Growth Inhibition*

P.I. Dr. Tim Seipel & Dr. Lovreet Shergill

Sorgoleone, a naturally occurring compound derived from *Sorghum bicolor* root exudates, exhibits herbicidal properties against certain weed species. An in-vitro study aimed at evaluating the efficacy of sorgoleone on monocot weeds was conducted in a randomized complete block

design with four replicates, seven sorgoleone doses (i.e., 0, 30, 50, 100, 150, 200, and 300 mg/L), and five weed species. Results indicate that increasing sorgoleone doses significantly reduced plumule length for all tested species. Based on PR50 (i.e., sorgoleone dose required for 50% plumule reduction), *Setaria viridis* (26.3 mg/L) was highly sensitive to sorgoleone, followed by *Avena fatua* (37.7 mg/L). PR50 values for other weed species, including *Aegilops cylindrica*, *Bromus tectorum*, and *Lolium persicum* ranged from 91.7 to 661.8 mg/L. Additionally, this study explores machine learning and computer vision approaches to measure plumule length accurately. The Computer Vision Annotation Tool (CVAT) software facilitated plumule length annotations, while computer vision models (YOLOv8) were utilized to detect plumules on pre-trained COCO or ImageNet datasets Pending field-level evaluation, this study suggests that sorgoleone could serve as a potential alternative for non-chemical sustainable weed management, showcasing the promising role of computer vision in facilitating data collection.

## Het Desai [g]

*Effect of relative humidity on glufosinate efficacy in Bassia scoparia and Chenopodium album populations*

P.I. Dr. Lovreet Shergill & Dr. Fabian Menalled

Glufosinate efficacy is positively correlated with relative humidity. In the semi-arid Great Plains, relative humidity often ranges from 25% to 35% during summer, which recurrently results in sub-optimal glufosinate efficacy. However, higher relative humidity (60%-80%) during early morning hours could aid in increasing overall glufosinate efficacy. We conducted a greenhouse study in a split-split plot design with three replications and two known glufosinate-susceptible *Bassia scoparia* (A. J. Scott and *Chenopodium album*) populations. Seven relative humidity levels, two nozzle types (e.gTeeJet-XR8002VS and TTJ60-110025), and two populations of each weed species were assigned to the main plots, subplots, and sub-subplots, respectively. Glufosinate-treated plants (0.6 kg ai ha-1 + 20 g L-1 ammonium sulfate) were exposed to elevated humidity (≥60%) for different durations (i.e.., 1-hour, 2-h, 4-h, 6-h, 8-h, and 21-days) and ambient humidity (25-35%) for 21-d. While glufosinate-treated *B. scoparia* exhibited 15-19% survival when kept in the ambient humidity, 0% survival was observed in ≥1-h of elevated humidity. *C. album* was completely controlled when plants were kept in elevated humidity for 21 days, whereas 60-100% survival was observed in all other humidity treatments. Results suggest that early morning application of glufosinate could efficiently manage *B. scoparia* but not *C. album*.

## Bridget Doyle [u]

PI: Dr. Michelle Flenniken

Honey bees (*Apis melifera*) are important plant pollinators in both wild and agricultural landscapes. Globally, annual pollination services are valued at ~175 billion dollars. Unfortunately, honey bee colony losses have averaged 38% per year in the United States since 2008. These losses are associated with multiple factors, including agrochemical exposure, limited floral resources, management practices, and pathogens. Most honey bee-infecting pathogens are viruses including deformed wing virus (DWV) and sacbrood virus (SBV). To combat virus infections, honey bees have evolved several antiviral defense mechanisms including conserved immune pathways (e.g., Toll, Imd, JAK/STAT) and dsRNA-triggered responses including RNA interference and a non-sequence specific dsRNA-mediated response. In addition, the heat shock stress response was shown to reduce replication of a model virus, but the role of this

response in limiting naturally occurring virus infections has yet to be determined. To investigate this, we examined the expression of two key heat shock response genes (i.e., heat shock protein 90 and protein lethal (2) essential for life-like) in DWV and SBV-infected bees and determined that their expression positively correlated with virus abundance.

## Jaye Griffin [u]

*Identifying Areas of the Barley Genome to Increase Drought Tolerance*

P.I. Dr. Jamie Sherman

This project's objective is to identify the effective areas of the barley genome that affect length. By utilizing the root roll-up technique, the phenotypic differences between the control samples and the Stay-Green grain should be easily identified. The quantitative trait loci (QTL) of the root length of barley have yet to be extensively researched. As no QTL has been done for the barley genome, this research will change barley growing. This QTL is a region of the barley genome associated with the length phenotype that varies from sample to sample. The co-locations of seminal root trait QTLs with grain fill duration and grain quality should be found. This was done by setting up, growing, and analyzing both the Stay-Green and control barley in root roll-ups. Root tracing and T-testing were also completed to identify the samples' quantitative differences. Furthering the viability of the Stay-Green samples, a longer root length is required to increase its drought tolerance and was found through testing. In addition to root length, other differences between the Stay-Green and the control samples were observable in the root rolls, such as sprout length and an increased number of roots. Climate change drastically changes the growing season of barley annually, and by finding an effective Stay-Green phenotype, the growing season of barley and crop yield will be stabilized.

## Samuel Koeshall [g]

*Influence of Environmental and Genetic Factors on Field Pea Protein and Yield*

P.I. Dr. Perry Miller

As market demand for plant protein sourced from yellow peas continues to grow, our general understanding of the factors that control protein concentration is poor compared to our understanding of factors that influence grain yield. Additionally, fractionation companies want to properly advise clients in prescribing management decisions that result in consistently growing high-protein, high-yielding yellow peas. Furthermore, yellow peas are grown across the northern and central Great Plains, leaving grain buyers wondering which specific growing region will consistently produce high protein, high-yielding yellow pea grain. Previous research in Montana has shown that environmental factors (e.g., precipitation and temperature) have a stronger control over protein concentration than genetics, although grain protein and grain yield have been shown to be positively correlated. While there are contrasting environmental conditions across the Great Plains, yellow pea varieties may perform differently across growing regions due to newer pedigrees or breeding efforts that emphasize yield over protein, and vice versa. Finally, there is limited knowledge on the relationship between grain protein and grain yield, which might be due to inter-environmental differences, of which varying genetics might also play a role.

## Wyatt Kray [u]

*Snowbank Isotope Modeling in R*

P.I. Dr. Stephanie Ewing

Due to their predictable seasonal variation in precipitation, the molar isotopic ratios of $O^{18}$:$O^{16}$ and $H^2$:$H^1$ in water molecules provide useful tracers for evaluating sources, fate, and transport of environmental waters through snowpacks and underlying soil columns. Changes in the isotopic composition of these isotopes provide insight into the effects of processes that favor either the heavier or lighter isotope. This study offers a portable, easily customizable model in R for predicting stable water isotope values in snowpack storage, snow-derived meltwater, and receiving soil water. We used inputs of air temperature and precipitation as predictors of snow accumulation and melt, where the form of precipitation and the magnitude of melt are simulated as functions of the difference in air temperature from the melting point. The isotopic composition of the snowpack is modeled from input precipitation isotope ratios and calculated by using volumetric mixing of the incoming precipitation and the remaining snow in the snowpack. We provide comparisons of model predictions and real data with this model to demonstrate its ability to reasonably approximate the isotopic composition of snow in a central Montana agricultural region, where understanding the contribution of snow to soil water is critical to non-irrigated agricultural management decisions.

## Emma Kubinski [g]

*Managing Weed Crop Competition in Future Climates: Evaluating the Impact of Elevated CO2 on the Critical Period of Weed Control*

P.I. Dr. Fabian Menalled

The rise in atmospheric carbon dioxide ($CO_2$) presents significant challenges to crop production due to its contribution to rising temperatures and extreme weather events. Just as consequential but less readily observed, increased atmospheric $CO_2$ can modify competitive interactions among crops and weeds. Despite various studies determining individual responses of crop and weed species grown in competition under high $CO_2$ concentrations, no research has directly evaluated how weed management recommendations could change. To address this knowledge gap, we assessed how the critical period of weed control (CPWC), a reference time that informs growers when to manage weed, will shift under predicted $CO_2$ levels in a growth chamber experiment using radish (*Raphanus sativa*) as a model crop and cheatgrass (*Bromus tectorum*) and buckwheat (*Fagopyrum esculentum*) as weeds, weedy and weed-free treatments were applied under ambient and elevated $CO_2$ conditions. We collected above and belowground biomass data and determined and compared the CPWC using a four-parameter log-logistic regression. Results demonstrate a reduction in the CPWC elevated $CO_2$ conditions in buckwheat, while findings with cheatgrass were inconsistent. This study provides critical insight into how weed management recommendations must adapt to future climate conditions.

## Sophie Lattes [g]

*Interseeding cover crops in carrots: establishment and weed management*

P.I. Dr. Mac Burgess Dr. & Fabian Menalled

Cover crops are widely touted for their soil improvement and weed management properties. However, their adoption in Montana has been hindered by high land prices and short growing

seasons. Interseeding cover crops in late-season vegetables is a potential solution that could allow farmers to adopt them without compromising their commercial enterprise. Additionally, weed management is a top concern identified by Montana's organic vegetable producers, particularly in densely seeded crops like carrots (*Daucus carota*). Interseeded cover crops may act as a biological barrier by filling space that would otherwise be used by more competitive weeds. However, little work has assessed the establishment of interseeded cover crops, and their potential as a weed management tool in horticultural systems. Thus, I am: 1) Evaluating the establishment of three interseeded cover crops [summer alfalfa, *Medicago sativa*), berseem clover (*Trifolium alexandrinum*), and annual ryegrass (*Lolium multiflorum*)], 2) assessing their impact on yield and quality of organic carrots, and 3) studying associated shifts in weed communities. Of the three cover crops, *L. multiflorum* had the largest biomass, yet cover crop identity did not largely impact carrot yield or weed communities. Results indicate that interseeded cover crops could be adapted by organic vegetable farms to improve sustainability.

## Aidan Manthey [u]

*Microbial Inoculants for Wheat*

P.I. Dr. Suchismita Mondal

This project will evaluate the impact of affordable microbial inoculants on spring and winter wheat varieties (*Triticum aestivum*). Multiple measures of quality will be used to understand the effects. These will include water use efficiency, seed emergence percentage, sap analysis, seed weight, crude protein content, overall yield, and tiller number. The study will be conducted in a greenhouse. The methods used will be manure tea, LWJMS (Lothair Wheat Jadam Microbial Solution), and vermitea. Microbial inoculants have been known to assist in nutrient assimilation. The key for sustainability in agriculture is efficiency.

## Grace Miller [u]

*Residual Herbicides in Soils Collected Along the Smith River Impact Plant Growth.*

P.I. Dr. Tim Seipel

Soil residual herbicides are defined as herbicides that remain active in the soil for an extended period. Additionally, these residual herbicides can affect plant emergence and can even kill sensitive plants. In this study, we conducted an experiment to test the effect of soil residual herbicides on the growth of lentils. We assessed soil provided by Montana Fish, Wildlife, and Parks from heavily managed locations along the Smith River for residual herbicides. Samples were collected from bare ground and vegetated areas at three sites along the Smith River. In an MSU greenhouse, we grew five lentil plants in five replicate pots for each of the six soils for six weeks. Each week we assessed plant height and herbicide damage and, at the end of the study, aboveground biomass. The results revealed that the control had the greatest lentil height and biomass and that the CC site had the highest amount of damage to the lentils. Additionally, there were no clear results regarding the differences between bare ground and vegetated ground cover types for lentil damage, biomass, and height. Overall, these results indicate that soil residual herbicides impact plant growth, although further research is needed to outline the exact effects.

## Skyler Ochs [u]

*Assessing Container Size Variability on Soil Organic Carbon Measurements*

P.I. Dr. Anthony Hartshorn

Soil organic carbon (SOC) and soil organic matter (SOM) are commonly used indicators of soil health because they generally both promote nutrient cycling and improve soil structure, infiltration, and water storage capacity. These can be inexpensively measured by the difference in the mass of oven-dry soil pre- and post-ignition. Loss on ignition (LOI) is done by burning oven dry soil in a furnace for 2 hours at 360°C. The size and shape of the container used determine the surface area to volume ratio of the soil sample, resulting in the potential for an extraneous variable. The goal of this study is to determine if the size of the container used for LOI affects the SOC % measured. LOI was done for A, Bt, and C horizons sampled in Bozeman, MT (n=258) using 33 mL crucibles alongside 5 different beaker sizes: 10 mL, short 20 mL, tall 20 mL, 30 mL, and 50 mL. It was determined that container size does result in different SOC %, though patterns varied based on the morphologic horizon. This study highlights the importance of procedure standardization for data reproducibility and for accurately assessing soil health.

## Sergei O'Sullivan [u]

*CRISPR/cas9 knockout lines in Montana wheat*

P.I. Dr. Mike Giroux

Climate change is creating ever-increasing challenges for plant breeding, requiring novel approaches to support expected population growth while combating newly founded abiotic and biotic side effects. Classical breeding approaches have primarily been favored due to a lack of regulations and consumer buying habits. Nevertheless, concerns have been raised as genetic gains using classical approaches are diminishing due to reduced genetic diversity in superior cultivars and issues surrounding linkage drag. Additionally, classical approaches are time- and resource-intensive. This presents a significant advantage for recombinant DNA technology in combating such issues. Transgenic approaches are highly regulated and contested by domestic and international consumers. The development of CRISPR/cas9 knockout has become increasingly popular in plant breeding and biological research due to its highly precise modifications, cost-effectiveness, and reduced regulations. The MSU wheat breeding program intends to employ this technology to further develop superior cultivars and gain insight into the molecular functions of various genetic components in spring, winter, and durum wheat.

## Keera Paull [g]

*Examining efficacy of immune stimulating compounds to limit honey bee virus infections*

P.I. Dr. Michelle Flenniken

Honey bees (*Apis mellifera*) are important pollinators of fruit, nut, oilseed, and vegetable crops, many of which are important for healthy human diets and valued at over $11 billion annually in the United States. Therefore, recent high annual honey bee colony losses (~38% per year) are alarming. Virus infections are one of the many factors that contribute to colony losses. Most bee viruses have positive-sense single-stranded RNA (+ssRNA) genomes, and replication occurs via a double-stranded RNA (dsRNA) intermediate. Honey bee antiviral defense includes sequence specific RNA-interference and non-sequence specific dsRNA triggered responses, as well as other canonical immune response pathways (e.g., NfkB, Toll, JAK/STAT). These responses are

induced by virus infections and other stressors, including phytochemicals. To further investigate honey bee antiviral defense mechanisms and the efficacy of promising compounds to stimulate these mechanisms and reduce virus infection levels, we infected bees with a panel of viruses with and without exposure to poly(I:C), a synthetic mimic of dsRNA, and thymol, a phytochemical produced by thyme plants (*Thymus vulgaris*). Our data indicate that both ingestion and injection of 3 µg poly(I:C) and consumption of 0.16 ppb thyme oil reduced viral load in honey bees.

## Amrit Poudel [g]

*Multi-environment Evaluation of Winter Pea Genotypes for Winter Survival and Yield Stability*

P.I. Dr. Kevin McPhee

Winter peas can be grown as a rotational crop for soil moisture conservation and nutrient recycling in the wheat-growing region of Montana. The development of winter hardy cultivars would increase seed yield and expand the area of adaptation of this crop. The objective of this study was to screen pea germplasm and breeding lines for winter survival and identify genotypes with good winter hardiness for future crop production. Field trials were conducted to evaluate genotypes at Bozeman, Havre, Huntley, and Moccasin, MT, in 2021, 2022, and 2023. Genotypes were evaluated based on the GGE biplot method. This analysis captured multiple variables, including yield, protein content, seed size, and overall stability across multiple years and locations of study, to aid in selecting lines. Higher winter survival was seen in Bozeman and Havre. A few lines were identified as having high seed yield and stable production over the years and in different locations. Breeding lines had higher mean yields, with a few good lines having stable production. Germplasm lines showed better winter survival. Larger seeds were observed in Moccasin, whereas Havre had the highest protein content. Protein content ranged from 20% to 31%. Mega-environment differentiation helped to select specific genotypes for a particular environment. The lines identified as having higher and stable yield and stress tolerance can be used as a prospective genetic resource in pea breeding programs.

## Meghan Robinson [g]

*Assessing Nitrate Leaching Risk in Irrigated Agricultural Fields*

P.I. Dr. Adam Sigler

Water is the primary limiting resource for crop production in semi-arid climates, and water management is critical for sustainable agriculture. Nitrogen is an important limiting resource as well, and its plant-available form nitrate is susceptible to leaching with deep percolation. Soil moisture management is a mechanism for controlling water and nitrogen use efficiency and is particularly relevant in irrigated systems where water application quantities and timings are decided by producers. We expect that implementing data-driven irrigation scheduling can reduce water and nitrogen losses. To explore interactions among soil properties, weather, and irrigation management, we are conducting research with cooperating producers in the Gallatin Valley on the Fairfield Bench. We installed soil moisture sensors to monitor soil water content over the summer of 2023, and collected water samples from lysimeters to assess nitrate concentrations. Field measured soil moisture was used to calibrate water flux models which were used for predicting deep percolation. Initial field work suggests that soil structure is an important control on water movement through soils. We observed evidence of soil moisture responses at depth, as

well as a sharp drop in nitrate concentrations during the growing season that suggests an opportunity for irrigation management to reduce nitrate leaching.

## Kieran Tharp [u]

P.I. Dr. Stephanie Ewing

The movement of atmospheric water through landscapes drives both water supply and water quality. Analysis of the isotopic composition of the water molecule (δ2H, δ18O) across geographic locations and over time allows for tracing source waters through landscapes. The isotopic composition of precipitation varies spatially as a function of local atmospheric conditions and also varies seasonally as a function of temperature, providing a means of tracing the supply and pathway of water entering soils. Global Network of Isotopes in Precipitation (GNIP) samplers were used to make monthly collections of meteoric waters at three sites in Montana: Lick Creek in Hyalite Canyon, Montana State University Horticulture Farm, and the Central Agricultural Research Center. In addition, we collected surface water samples from Rosebud Creek (south of Colstrip, MT), Hyalite Creek, Louse and Porter Creeks in Central Montana, and the Upper Clark Fork River. We create a Local Meteoric Water Line (LMWL) for each GNIP site for comparison across locations and with proximal surface water. We also compare LMWLs from measured values to LMWLs created using the Online Isotopes in Precipitation Calculator (OIPC) developed by the University of Utah.

## Brandon Tillett [g]

*Altering Flowering Time in Wheat for Yield Stability Amidst a Changing Climate*

P.I. Dr. Mike Giroux

Climate change has extended the growing season in Montana by 12 days since 1950. Early July, the time of pollination for spring wheat, has been getting hotter, creating challenges for pollen integrity and yield stability. This study is focused on three different genes in spring wheat that impact the timing of floral development and pollination. There are three copies of each gene in spring wheat, creating nine opportunities to alter flowering time by a day or so. Utilizing the groundbreaking CRISPR technology, lines are under development that vary for all nine of these genes in spring wheat, which will result in a large window of different flowering times. These lines will be tested around the state at various experimental stations to determine the best timing of wheat floral development to maintain yields across the different regions of Montana.